PB86-155686

Environmental and Occupational Health Regulations in the U.S. Lead Industry

(U.S.) Bureau of Mines, Washington, DC

1986

U.S. Department of Commerce
National Technical Information Service

BuMines OFR 3-86

PB86-155686

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

ENVIRONMENTAL AND OCCUPATIONAL HEALTH REGULATIONS IN THE U.S. LEAD INDUSTRY

by

Carl W. Anderson, Paul T. Behum and Frederick W. Miller

Bureau of Mines Open File Report 3-86

1986

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50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. BuMines OFR 3-86	2.	3. Recipient's Accession No. PB86 1566867/AS

4. Title and Subtitle Environmental and Occupational Health Regulations in the U.S. Lead Industry	5. Report Date Jan. 1986
	6.
7. Author(s) Carl W. Anderson, Paul T. Behum, and Fredrick W. Miller	8. Performing Organization Rept. No.
9. Performing Organization Name and Address U.S. Bureau of Mines Div. of Minerals Policy and Analysis 2401 E Street, NW. Washington, DC 20241	10. Project/Task/Work Unit No.
	11. Contract(C) or Grant(G) No. (C) (G) NA
12. Sponsoring Organization Name and Address Office of Assistant Director--Mineral Data Analysis Bureau of Mines U.S. Department of the Interior Washington, DC 20241	13. Type of Report & Period Covered In-house research
	14.

15. Supplementary Notes

Approved for release January 23, 1986.

16. Abstract (Limit: 200 words)

This report presents a Bureau of Mines study of regulations pursuant to four major environmental and occupational health laws and the compliance problems of primary and secondary lead smelters and lead-acid battery manufacturers. Technical feasibility and difficulties in implementing and administering the following standards are addressed: (1) the Occupational Safety and Health Administration standards for occupational exposure to lead, (2) the Environmental Protection Agency (EPA) national ambient air quality standard for lead, (3) the EPA hazardous waste management regulations pertaining to recycling of lead, and (4) the EPA effluent limitations under the Clean Water Act and amendments. Although alternative technologies for lead production are emerging and engineering controls are available for retrofitting existing facilities, the economic viability and universal adaptability of these measures are uncertain. Additional pilot and demonstration plant tests may be required for new lead smelting and refining processes. Regulatory approaches in dealing with compliance problems on a plant-by-plant basis would be beneficial. Such an approach should consider the technical and economic feasibility of engineering controls on existing processes and take into account the level of development of new processes.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

Primary lead smelter
Secondary lead smelter
Lead refining

c. COSATI Field/Group

18. Availability Statement Release unlimited by NTIS.	19. Security Class (This Report) Unclassified	21. No. of Pages 77
	20. Security Class (This Page)	22. Price $11.95

(See ANSI-Z39.18) See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

This Bureau of Mines open file report summarizes problems that the U.S. lead industry has in complying with regulations pursuant to four major environmental and occupational health laws. The report is preliminary and has not been edited or reviewed for conformity with Bureau of Mines standards and nomenclature. Work on this study was conducted by personnel from the Division of Minerals Policy and Analysis, 2401 E Street, N.W., Washington, D.C. 20241, and the former Eastern Field Operations Center in Pittsburgh, PA.

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ENVIRONMENTAL AND OCCUPATIONAL HEALTH REGULATIONS IN THE U.S. LEAD INDUSTRY

by

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ABSTRACT

This report presents a Bureau of Mines study of regulations pursuant to four major environmental and occupational health laws and the compliance problems of primary and secondary lead smelters and lead-acid battery manufacturers. Technical feasibility and difficulties in implementing and administering the following standards are addressed: (1) the Occupational

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Safety and Health Administration's standards for occupational exposure to lead; (2) the Environmental Protection Agency's National Ambient Air Quality standard for lead; (3) the Environmental Protection Agency's hazardous waste management regulations pertaining to recycling of lead; and (4) the Environmental Protection Agency's effluent limitations under the Clean Water Act and amendments. Although alternative technologies for lead production are emerging, and engineering controls are available for retrofitting existing facilities, the economic viability and universal adaptability of these measures are uncertain. Additional pilot and demonstration plant tests may be required for new lead smelting and refining processes. Regulatory approaches in dealing with compliance problems on a plant-by-plant basis would be beneficial. Such an approach should consider the technical and economic feasibility of engineering controls on existing processes and taking into account the level of development of new processes.

INTRODUCTION

This study was initiated to examine the potential cumulative impact of environmental and health and safety regulations on the U.S. lead industries. The study was confined to the smelting, refining, and integrated battery sectors of the lead industry and four major regulations that impact the industry.

The United States consumes over 20 percent of the world's lead production and there are few economic substitutes for it in most of its major applications. Approximately two-thirds of this consumption is in the production of lead-acid storage batteries, primarily used in starting, lighting, and ignition (SLI) systems for vehicles. Lead is a toxic material. Historians have traced the toxic effects of lead on people back 2,000 years. Lead is among the most recyclable of materials with about 90 percent of the lead in spent batteries recycled. The toxicity of lead makes recycling desirable.

Three well-defined sectors have evolved in the U.S. lead industry: the primary sector in which lead is smelted from sulfide ores; the secondary sector in which lead is recycled from spent batteries, metallic scrap, and chemical compounds; and the battery sector, in which a significant number of facilities are integrated backward into secondary lead production. Regulation has affected these sectors differently because of their differing structures and the differences in the application of regulations to each sector.

The study was conducted from December 1982 through September 1983 and revised and updated June and July 1984. The project team visited industrial plants and corporate offices at 12 locations in the midwestern and eastern United States. As a result of discussions with industry representatives at these facilities, the focus of the study centered on the following regulatory areas:

(1) The OSHA standard for occupational exposure to lead.

(2) The EPA national ambient air quality standard for lead and related concerns under the Clean Air Act.

(3) The EPA hazardous waste management system pertaining to recycling of lead under the Resource Conservation and Recovery Act of 1976 and Congress' temporary exemption of primary lead producers from hazardous waste regulations.

(4) The EPA effluent limitations and requirements for each of the three sectors under the Clean Water Act.

ACKNOWLEDGMENTS

The project team acknowledges Mr. William D. Woodbury of the Bureau's Division of Nonferrous Metals for his indispensable assistance in this study. Mr. Woodbury presently serves as the Bureau's commodity specialist for lead. The project leader also acknowledges the contribution of the late Mr. John A. Rathjen who formerly served as the Bureau's lead specialist. Mr. Woodbury and Mr. Rathjen provided insight and background information and assisted in establishing contact with industry representatives.

The project team also thanks Dr. Sam J. Fraser of the Bureau's Division of Minerals Policy and Analysis for his assistance in the analysis. Dr. Fraser made a major contribution to the chapter on the Clean Air Act and the national ambient air quality standard for lead.

The project team also expresses gratitude to the many industry representatives who provided valuable information essential to the study.

CHAPTER 1.—THE STRUCTURE OF THE U.S. LEAD INDUSTRY: THE PRIMARY, SECONDARY, AND BATTERY SECTORS

In terms of tonnage consumed, lead is the fourth-ranked nonferrous metal after aluminum, copper, and zinc. The transportation sector ultimately claims about 75 percent of all end uses for lead, and about 66 percent of total consumption is in lead-acid storage batteries. Starting, lighting, and ignition (SLI) systems for vehicles and industrial batteries comprise about 90 percent of lead-acid battery use. Other major uses of lead include anti-knock additives for gasoline (tetraethyl lead, or TEL), paints and pigments, ammunition, solder, radiation shielding, and electrical sheathing (1,2,3,4).

The United States consumed 22 percent, or 1.2 million metric tons1/ of the lead consumed worldwide in 1983. The Bureau of Mines has forecast U.S. annual demand for lead to range between 1.1 and 2.2 million tons by the year 2000, with a probable demand level of 1.6 million tons. This represents an average annual demand growth rate of about 1.3 percent.

Although the United States is a large importer of lead metal, the risk of supply disruption is relatively low. First, Canada and Mexico are the main sources of imported metal for the United States and are among the world's leading producers. Second, the United States has the world's largest secondary lead sector that historically has produced over 50 percent of total U.S. production. Third, the United States has about one-fifth of the world's total identified reserves of lead ores. These ores are of high grade and are highly competitive in world markets (3).

From 1980 through 1983, demand for lead was relatively low because of the weak domestic automobile and construction markets. Also, advancements in battery technology have reduced the size and weight of SLI batteries. However, in 1984 an increase in the consumption of lead was noted for other end use products of lead. Domestic consumption, especially by the lead-acid storage battery sector, increased in 1984 to the highest level since 1979.

The U.S. average price for lead has been gradually declining since August 1979, when an average price of about 52.6 cents per pound was reported. During 1982 the weighted-average price declined to 25.5 cents per pound, the lowest since 1976. In constant dollars, this was the lowest price since 1962. The decline stabilized within a range of 19 to 20 cents per pound in the latter half of 1983, but below estimated average U.S. production costs (3,5). Depressed lead metal prices have had adverse ramifications for both primary and secondary producers, especially because of worldwide over-production coupled with little growth anticipated for short-term demand. During 1982 the primary mining and smelting sector operated at roughly 87 percent of total capacity. The secondary producers, however, faced high production costs and

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1/ Aggregate totals in this chapter are reported in metric tons (2,204.6 lbs.) however, U.S. lead producers normally report capacities and expansions in short tons (2,000 lbs.).

depressed metal prices along with a 50 percent overcapacity in the sector. A shortage of available scrap at acceptable profit margins caused the entire secondary sector to operate at various levels of curtailment during 1982, resulting in intermittent operations or temporary closures throughout the sector, and bankruptcy for numerous small or marginal operators (6).

Five intermediate to large secondary facilities with a combined capacity of 59,000 tons closed permanently during 1982, although this loss was more than offset by 67,000 tons of new capacity that opened during the year; in 1983 about 43,000 tons of secondary capacity was closed permanently (4). Three major secondary lead producers filed for reorganization under Chapter 11 of the Federal bankruptcy laws in 1982; however, secondary capacity remained at over 1.2 million metric tons at year end. The secondary sector still produced 53 percent of the metal relative to demand in 1982 (4).

A. INDUSTRY STRUCTURE

The battery manufacturing sector is integrated into the secondary smelting sector with some of the largest battery producers being major secondary lead producers. For example, in 1981 six integrated battery manufacturers produced about 40 percent of the total U.S. secondary lead output of 641,105 metric tons (1). In 1981 there were about 90 firms, including integrated battery manufacturers, producing secondary lead throughout the United States. The diversity of secondary producers is due to the nature of the secondary business; that is, the requirement to be located close to scrap supplies and to the battery manufacturing plants. There are currently about 40 secondary plants that have individual capacities of over 5,000 metric tons per year, and they range in capacity to over 80,000 metric tons per year.

Locations and capacities of U.S. primary lead smelters and refineries operating in 1981 are shown in Figure 1-1. In 1981 these plants produced 498,331 metric tons, or 44 percent of the total U.S. production. The Bunker Hill smelter at Bradley, Idaho, closed indefinitely near the end of the 1981 leaving only three companies that produce primary lead metal in the United States. Bunker Hill was closed because the parent company, Gulf Resources and Chemical Corp., projected 1981 losses for the facility at $21 million, with no anticipated profitability in the near term. (1, 3). In 1982 primary lead production was consequently lower, at 468,000 metric tons. The fully operational capacity of the primary smelter sector was reduced from 715,000 to 595,000 tons by the Bunker Hill facility closure. The 60,000 tons per year (200 tons per day) secondary lead smelter of National Smelting in Pedricktown, NJ had smelted limited amounts of sulfide concentrates in 1983, but the facility closed (5).

Production figures for the primary and secondary lead sectors are presented in Table 1-1. Primary production is classified (1) from domestic ores and base bullion, (2) from foreign ores and base bullion, and (3) as antimonial lead.

Charles River Associates (CRA) identified 136 domestic battery plants in 1982 for an environmental and economic impact analysis of the Occupational Safety and Health Administration's standard for occupational exposure to lead (6). CRA noted that 63 of the plants accounted for approximately 94 percent of the total industry capacity for SLI batteries. For purposes of its study, CRA classified battery plants under the following categories (6):

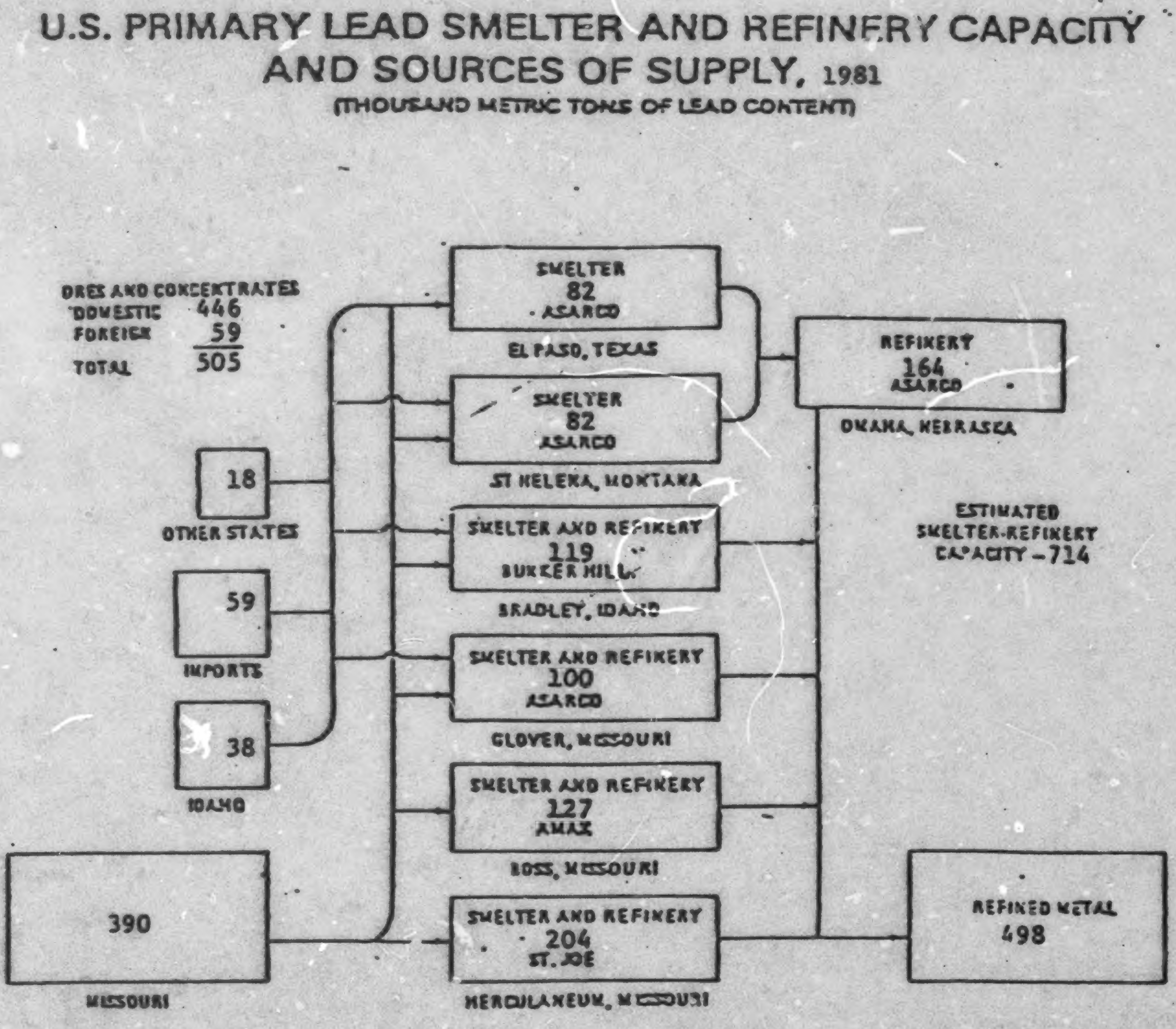
U.S. PRIMARY LEAD SMELTER AND REFINERY CAPACITY
AND SOURCES OF SUPPLY, 1981
(THOUSAND METRIC TONS OF LEAD CONTENT)
ORES AND CONCENTRATES
DOMESTIC 446
FOREIGN 59
TOTAL 505
18
OTHER STATES
59
IMPORTS
38
IDAHO
390
MISSOURI
SMELTER
82
ASARCO
EL PASO, TEXAS
SMELTER
82
ASARCO
ST HELENA, MONTANA
SMELTER AND REFINERY
119
BUNKER HILL
BRADLEY, IDAHO
SMELTER AND REFINERY
100
ASARCO
GLOVER, MISSOURI
SMELTER AND REFINERY
127
AMAX
BOSS, MISSOURI
SMELTER AND REFINERY
204
ST. JOE
HERCULANEUM, MISSOURI
REFINERY
164
ASARCO
OMAHA, NEBRASKA
ESTIMATED
SMELTER-REFINERY
CAPACITY - 714
REFINED METAL
498

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FIGURE 1-1. U.S. primary lead smelter and refinery capacity, and sources of supply.

Table H—Salient lead statistics

(Metric tons unless otherwise specified)

	1980	1981	1982	1983	1984
United States:					
Production:					
Domestic ores, recoverable lead content	550,366	445,535	512,516	[r]449,316	323,837
Value ---- thousands	$515,109	$355,021	$285,579	[r]$214,768	$251,866
Primary lead (refined):					
From domestic ores and base bullion	500,189	440,328	459,965	459,369	330,183
From foreign ores and base bullion	50,437	55,965	52,296	55,227	65,409
Antimonial lead (primary lead content)	841	3,098	4,622	W	W
Secondary lead (lead content)	676,578	641,106	571,[illegible]	509,591	582,153
Exports (lead content):					
Lead ore and concentrates	27,616	25,043	[illegible]4	[illegible]119	11,898
Lead materials excluding scrap	104,458	23,230	[illegible]	[r]24,251	16,862
Imports, general:					
Lead in ore and matte	44,695	55,545	[illegible]7	47,616	66,679
Lead in base bullion	296	449	19	58	42
Lead in pigs, bars, reclaimed scrap	98,026	107,185	96,457	[1]179,465	167,868
Stocks, Dec. 31 (lead content):					
At primary smelters and refineries	125,954	140,207	125,127	106,661	136,079
At consumers and secondary smelters	136,214	123,216	97,299	100,771	97,072
Consumption of metal, primary and secondary	1,070,368	1,167,101	1,075,408	1,148,407	1,207,083
Price: Common lead, average, cents per pound[2]	42.46	36.53	25.54	21.66	25.55
World:					
Production:					
Mine ---- thousand metric tons	[e]3,473.7	[e]3,369.7	3,441.8	[p]3,302.2	[e]3,190.4
Refinery[3] ---- do.	[e]3,169.4	[e]3,126.6	3,180.6	[p]3,231.2	[e]3,152.9
Secondary refinery ---- do.	[e]2,290.5	[e]2,211.5	2,080.1	[p]2,092.9	[e]2,138.5
Price: London Metal Exchange, pure lead, cash average, cents per pound	41.22	32.20	24.66	19.27	20.12

[e] Estimated. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing company proprietary data.

[1] Includes Bureau of Mines estimate of 42,000 metric tons of pigs and bars (lead content) of U.S. brands returned from the London Metal Exchange.

[2] Metals Week. Transactions on a delivered basis.

[3] Primary metal production only. Includes secondary metal production where inseparably included in country total.

(1)	Large SLI (Over 750,000 batteries per year)	47 plants
(2)	Intermediate SLI (From 300,000 to 750,000 batteries per year)	16 plants
(3)	Small SLI (Under 300,000 batteries per year)	53 plants
(4)	Industrial	20 plants
	TOTAL	136 plants

Profitability and Ability to Comply with Regulations

The cost of resources affects the ability of primary and secondary producers and integrated battery manufacturers to upgrade their facilities to meet environmental and health and safety standards. This is particularly true during recessionary periods such as the United States experienced from 1981 through 1983. Further, the three sectors have different cost structures concerning the cost of source materials, and the ability to pass on these costs in different ways.

Most primary smelting facilities in Missouri have fixed raw material costs because they are vertically integrated into mining and ore beneficiation to a large degree. All Missouri primary smelters will probably be integrated into mining by the end of 1985 (3, 6). In 1981, over 70 percent of all primary smelting capacity and over 90 percent of lead mining capacity was located in Missouri.

Integrated primary producers are generally reluctant to close down mines even for short periods because conditions in inactive mines tend to deteriorate rapidly and reactivation costs are high. Therefore, in the short-term integrated primary producers can continue to operate at a loss to take advantage of fixed raw-material costs, avoiding mine closure and start-up costs. Because they have high fixed costs and relatively low operating costs, primary producers seldom vary production according to changes in prices (6).

Primary custom smelters are somewhat more dependent upon the "spread" between the U.S. lead producer price (the market price for refined lead metal) and their smelting costs for treating ores from independent mines. However, these smelters receive a premium for recovering higher valued metals such as zinc, silver, gold, copper, and antimony from more complex western and foreign ores. Recovery of these metals as coproducts or byproducts is often the determining factor in maintaining profitability of toll smelting or mining operations. Custom smelters may or may not toll concentrates. Generally, large custom smelters prefer to purchase concentrates outright in preference to toll contracts. Toll contracts are often utilized by custom smelters to maintain production and reduce financial risk in periods of variable lead prices. Alternatively, toll contracts can allow a custom smelter to pass on the costs for some impurities, such as arsenic, by charging penalties that would help cover the cost of removal of these metals. Integrated battery manufacturers are in a somewhat better position than non-integrated secondary producers concerning costs for source material—lead scrap.

Non-integrated secondary lead smelters must depend upon bidding for lead scrap to obtain a source of feed material, unless they are under a tolling contract with a non-integrated battery manufacturer or another secondary smelter processing metallurgical wastes. A few domestic secondary smelters with the capacity to process sulfide ores and wastes have done so on a limited basis, especially since the closure of the Bunker Hill smelter. However, most secondary producers operate on the "spread" between the scrap bidding price and the U.S. producer price for lead. The spread is a relatively fixed margin whereby changes in the lead producer price are partially passed backward to scrap dealers. In strong economic times, this spread will be large enough to cover the producer's processing costs and allow a profit margin. However, during the latter half of 1982 and in 1983, when refined metal prices were very low and the scrap bidding price was depressed, independent scrap dealers began to stockpile used batteries and lead scrap metal in speculation of higher prices, or they traded outside the United States where higher prices were offered. The spread has not been large enough to insure a profit for most secondary producers and some scrap shortages have occurred. This is largely the reason why many have temporarily (and in some cases permanently) closed their operations. Those remaining in business have maintained operations by charging a premium on contained antimony to customers of antimonial lead.

As the price of refined metal drops, secondary operators reduce bids for delivered scrap accordingly. However, at some bidding level, about 10 to 12 cents per pound, the scrap dealers will not deliver scrap. Since early 1982, refined lead metal prices have been under 30 cents per pound, so secondary producers having total processing and scrap costs in excess of the metal price have been operating at a loss on soft lead (lead that is 99.94 percent pure) (3, 5). The numbers used above are approximations, and operating costs and scrap prices vary with time and region.

Recently, some secondary operators have increased their dependence on toll production to sustain their operations. Toll production is metal that is smelted and often refined for another firm, usually a battery manufacturer or another secondary producer, under contract. Historically, secondary firms have limited tolling arrangements to about 30 percent or less of their total production to maintain free capacity that could be used to take advantage of increasing spreads between refined metal and scrap bid prices. In a declining metal market, however, toll agreements become more attractive to the independent producer (3).

Competition Between Primary and Secondary Producers

The development of calcium-lead alloys and "hybrid" low antimony and calcuim-lead systems for low-maintenance SLI batteries in vehicles has resulted in increased direct competition between primary and secondary lead producers. Formerly, primary and secondary producers had differentiated products that insulated them from major direct competition with one another. The primary operators produced higher-grade lead such as the Corroding Grade (minimum 99.99 percent) and soft lead (minimum 99.94 percent lead) used for the production of lead oxides and other lead chemicals. The secondary producers produced mainly antimonial or "hard lead," various antimony-lead alloys used for batteries. They had an advantage over primary operators in that they were recycling antimonial lead from spent batteries with little refining and antimony additions, whereas the primary producers had to purchase and add antimony to the lead they smelted from ores (3, 6).

In 1977, due to domestic demand, calcium-lead and other new alloys for low-maintenance SLI batteries began to replace antimonial lead, and the soft lead produced by primary operators was useful for calcium-lead applications. To remain competitive, a number of the larger secondary producers installed reverberatory furnaces for smelting and added refinery capacity to remove antimony and other impurities from recycled lead. Thus, they could produce soft lead for the new battery alloy market and could also supply the markets for chemicals, pigments, and solder. By 1980, most of the larger battery manufacturers had converted much of their capacity to calcium-lead and other low maintenance battery alloy-based production; and by 1982, over 75 percent of all SLI battery capacity had been converted (4). The primary producers have been able to penetrate the battery market to help replace other markets lost, such as the gasoline additive market.

Small secondary producers are at a relatively greater disadvantage because they are largely dependent upon blast furnace smelting technology that cannot remove antimony from lead. Nevertheless, there are certain historical markets, such as telephone and computer standby systems and heavy industry traction batteries, that depend upon antimonial lead. Also, there is a growing "hybrid alloy" SLI battery market that requires low-antimonial-content alloys. Specialization in applications has helped keep some of the smaller secondary operators in business (3). Smaller integrated secondary producers have maintained sufficient profits from their manufacturing sectors to improve their refining capabilities for new battery alloy production.

B. SMELTING AND REFINING PRACTICES

Primary Lead Metal Production

To reduce lead ore concentrates to metal, conventional smelting is normally conducted in two steps, oxidative roast sintering and reducing blast furnace smelting (6). The sintering step is normally in a separate smelter facility and is necessary to remove most of the contained sulfur; but more important it produces a hard, homogeneously agglomerated and porous material termed sinter. The sinter is smelted in a shaft-type blast furnace to produce a crude lead bullion for subsequent refining. Prior to sintering, the complex charge is combined with other lead-rich process secondary materials and sinter fines; with dilutants, normally blast furnace slag; fluxes; and, at some plants, coke breeze (8).

Modern sintering is an automated roasting process whereby a layer of charge is spread on a continuous loop of linked, grate-bottomed pallets. The charged pallets are first moved over a burner that ignites the charge, and then over a series of wind boxes arranged in an updraft or downdraft configuration providing the necessary air for combustion of the concentrate sulfur and coke breeze.

The sinter must be processed to produce a well-sorted size suitable for shaft furnace reduction. Sizing is obtained by a series of crushers and screens with fine-grained sinter being recycled to the sinter feed and the coarser material conveyed to the top of the blast furnace. About 45 to 55 percent of the recycled sinter forms the sinter charge. Recycling sinter is expensive in terms of material handling and fugitive dust control, and is one of the major drawbacks of the two-step conventional blast furnace process.

Domestic primary refining processes are dependent on the complexity of lead ores smelted. Custom smelters and refineries process more complex western U.S. and foreign ores utilizing traditional pyrometallurgical (fire) refining methods (9). Refineries processing ores of the new Missouri lead belt which are relatively high in copper (0.1 percent), low in arsenic, antimony, and bismuth, but contain significant silver (0.01 percent), are required to use unique copper drossing practices, but otherwise have a simplified refining process (9, 10).

Secondary Lead Metal Production

Secondary lead is recovered from scrap, product wastes, refinery drosses and residues. Most secondary lead is derived from fabricated products such as battery plates and oxides. Such material is remelted and refined in secondary smelters to produce soft lead and antimonial lead or other lead-base alloys. Additional secondary lead is recovered from process scrap, largely drosses and residues generated during the fabrication of lead products, and recycled to secondary smelters for production of refined lead. Some secondary lead materials are reused after remelting without refining, but an increasing proportion is processed in refineries because of the need to meet customer specifications. Secondary materials have provided over 50 percent of U.S. requirements in recent years. The chief source of secondary lead is automobile storage batteries that have been scrapped after use. About 90 percent of the lead used in the manufacture of storage batteries is recycled. Battery breaking and sorting precedes smelting, and there is a wide variety of ways in which secondary producers break and sort batteries (11).

The vertical blast furnace has been the dominant secondary smelting furnace, but the reverberatory furnace in combination with a blast furnace has also been used (11, 12). There has been some influx of foreign technology in the domestic industry. The 22,000 ton-per-year smelter of Bergsoe Metal Corp. at St. Helens, Oregon, is one of the more notable examples. Several domestic smelters utilize the short rotary furnace (SRF) popular at foreign smelters as the production furnace, and others operate the SRF to smelt in-plant intermediate products, by-products, and waste materials (11, 12, 14). One large domestic smelter utilizes a long rotary kiln following the technology developed by Preussag AG at its Goslar, West Germany, smelter (7). Small recyclers and battery plant scrap remelters use inductive (electric) or hydrocarbon-fueled pot furnaces to simply remelt lead scrap.

CHAPTER 2. - ENVIRONMENTAL AND HEALTH EFFECTS OF LEAD PRODUCTION AND SOURCES OF LEAD EMISSIONS

A. ENVIRONMENTAL EFFECTS

Introduction of lead and associated heavy metals generated by the lead industry into the environment is a highly complex process. Airborne transport of lead is a major means of soil and water lead contamination. Inhalation of airborne lead is a major source of exposure to humans near smelters. Contamination of land and water is critical in terms of accumulation of toxic metals in the human food chain.

The soil system constitutes the major sink for deposition of airborne heavy metals in the terrestrial ecosystem. Automobile exhaust is the principal contributor of lead to the soil (15). Nevertheless, emissions from primary and secondary lead smelters and to a lesser extent mining and milling operations contribute significant quantities of lead and associated heavy metals to the soil. Although source characteristics are important, the contamination area is more localized and largely a function of the soil nature (16). Associated cadmium has the ability to remain highly soluble making it more available to plants and other biological organisms to which it is highly toxic (17, 18). Lead uptake by animals has been estimated to amount to as great as 10 percent of dry matter ingestion (19). In some cases, animals have died as a result of lead poisioning (20, 21). Involuntary human ingestion and inhalation of metal-rich dust can also occur in areas with contaminated soil. Plants, if contaminated, may introduce toxic heavy metals into the human food chain. However, plants, in general, are very tolerant of inorganic lead compounds. Plants may acquire lead by two paths; absorption by roots from the soil, and absorption of lead deposited on the leaves. Alteration of soil conditions to make lead more available in soil solutions increases root uptake. Although under some conditions large amounts of lead may be taken up by plant roots, small amounts are translocated to other parts of the plant (22, 23).

Lead deposited on aerial portions of a plant contribute little to translocation and incorporation of lead into the plant (23). Lead contamination of the aquatic ecosystem has the potential for harmful effects through bio-accumulation within the hierarchy of the human food chain.

B. EFFECTS ON HUMAN HEALTH

Principal pathways for lead absorption by the human body are inhalation, ingestion, and placental transfer. Inhalation is generally the dominant route of entry, with ingestion secondary in importance. The fetus is at the greatest risk to harmful effects of lead poisioning and fetal blood lead (PbB) levels have been shown to be reflective of the mother's PbB level. (24, 25, 26).

Exposure to airborne lead poses the greatest risk of absorption, it is estimated that as much as 50 ± 10 percent of the lead deposited in the lung is absorbed (24). The extent of absorption of lead varies in response to many factors, including: age, depth of respiration, nutritional status, and personal habits (24, 27).

Following absorption, lead is transported by the bloodstream to various body tissues and organs. Bones have the highest affinity for lead, accumulating over 90 percent of the body burden (24).

The lead body burdens of humans generally reflect levels of lead in the surrounding environment. Concentration of lead in whole blood is often used as an indication of lead body burden. PbB is usually measured in either micrograms per deciliter (µg/dl) or micrograms per 100 grams (µg/100g) of whole blood. For most applications, the differences in these units are ignored, but they can be significant for certain cases (28). Inhabitants of densely populated urban areas where lead levels are high due to automobile exhaust have PbB levels higher than the general population. Factors contributing to PbB levels include automobile exhaust, lead based paints, and processed food.

Studies of the chronic health effects caused by lead poisoning on the human body indicate that PbB levels greater than 40 µg/dl in normally healthly children and 50 µg/dl in adults are approximately the lower limits at which poisoning by lead begins. Acute, permanently damaging, or fatal levels are about 100 µg/dl for children and 120 µg/dl for adults. The subtle biochemical disturbances brought on by low levels of lead in the b[illegible] are subject to varying interpretations (29).

C. LEAD EMISSION SOURCES

Virtually every step in lead processing is a potential source of contamination. The atmosphere is the major transport and distribution medium for emissions resulting from the pyrometallurgical processes employed in smelting lead. Lead dust created by mining and beneficiation processes in the form of lead sulfide (PbS) remains relatively stable in the environment and apparently causes little adverse impact. Smelting of sulfide ore yields more reactive forms such as lead oxide (PbO), lead sulfate ($PbSO_4$), mixed compounds (such as $PbSO_4 \cdot PbO$) and elemental lead (30, 32). In such forms lead may be more available for incorporation into various components of the ecosystem. Associated heavy metals in smelter emissions, particularly cadmium, also have harmful impacts on the surrounding ecosystems (33, 34, 35, 36). Combustion of coal, coke, and natural gas produce sulfur dioxide and carbon monoxide in substantial quantities. Most of the carbon monoxide produced is necessary for the reduction of lead to metallic form or is oxidized in the flues to carbon dioxide.

Atmospheric emissions have been categorized into two principal sources:

> Stack emissions, generated by processing, are exhausted after passing through primary pollution control systems. Such emissions are submicron in size.
>
> Fugitive emissions escape from operations into the atmosphere without collection by exhaustion through existing pollution control and exhaust systems. A large percentage of fugitives are made up of coarse particulates which settle rapidly in the vicinity of the smelter (40, 41).

Water is used extensively throughout the smelting industry and may accumulate lead and associated heavy metals in a dissolved or suspended solid state. The major source of water contamination is the milling-concentrating process. Waste water may contain high levels of lead and related metals in conjunction with organic chemical beneficiation reagents that can be toxic in the aquatic ecosystem (42).

Deposition of lead-bearing emissions and solid waste disposal by the industry are significant contributors to land pollution. Preliminary studies in the New Missouri Lead Belt region have noted a decrease in the microbial population in soil surrounding smelter complexes and suggest that this may be related to lead contamination of the soil (31).

A general outline of environmental hazards related to the primary and secondary industry is given in Table 2-1.

Primary Lead Industry Sources

Mining and Milling

Mining of lead ores in the United States occurs almost exclusively in underground operations. Dust generated by drilling, blasting, crushing, loading, and transport is estimated at 110 grams per metric ton (g/mt) of ore (42). Wastewater produced in mining operations presents a serious environmental concern. Principal sources of wastewater include: seepage of surface waters through spoil piles; interception of the water table by mine workings; and water used in the mine for utility purposes (31, 32). The degree of contamination of mine water is largely a function of the solubility of the ore. The solubility of the ore is directly dependent on water acidity and the mineralogy of the ore body. In addition to metal contaminants, waste water from the mines may contain varying amounts of diesel fuel, oil, and blasting residues (31).

Control measures to prevent the release of contaminated mine water into surface waters incorporate impoundment and pH adjustment to precipitate heavy metals (48). After sufficient time for settling of metal contaminants, water can be either released or recycled to mining or milling operations.

The milling process consists of crushing and grinding ore for concentration and flotation. Lead-bearing emissions are generally fugitive and consist of coarse particulates of relatively insoluble galena. This type of emission settles a short distance from the point of generation, causing relatively minor local environmental impacts (31). In addition, total atmospheric emissions generated by transfer, storage and transport of ore are only estimated at 2.1 kilograms per metric ton (kg/mt) of ore handled (31, 41, 44).

Gravity and flotation concentration methods involve the use of water treated with organic chemicals. Following the removal of recoverable metals, the wastewater is pumped as a slurry to impoundment ponds. This wastewater contains varying amounts of suspended solids, such as gangue and unrecovered ore-minerals (mostly sulfides), dissolved metals, and excess organic reagents (31, 42).

Table 2-1. - Environmental pollutants associated with the primary and secondary lead industry

Process Step	Air Emissions	Water Effluents	Solid Waste
Primary			
Mining	Dust from above ground ore transfer points and transportation, entrained dust from tailings and ore piles.	Acid mine drainage (AMD), excess heavy metals, blasting residue in tailings and ore pile runoff.	Tailings piles.
Milling	Crushing, grinding, and transportation dust, entrained dust from tailings, concentrate and ore storage piles.	Suspended solids, excess heavy metals, and organic flotation process reagents in concentrator wastewater. Runoff from tailings, concentrate, and ore piles can contain AMD, excess heavy metals and blasting residue. Runoff from mill site could contain excess heavy metals and flotation reagents. Tailings pond leakage with flotation reagents and excess heavy metals.	Tailings piles or ponds.
Smelting and refining	Process waste gas emissions containing lead, copper, zinc, cadmium, antimony, sulfur dioxide and carbon monoxide.	Waste water from slag granulator and wet scrubbers, acid plant blowdown and smelter water, runoff from smelter grounds, and raw material storage piles containing excess heavy metals, flotation reagents, and AMD.	Slags, drosses, and skims; scrubber and water treatment plant sludge; washdown, flue, and vacuum dusts; and acid plant gypsum disposal.
Secondary			
Battery breaking	Fugitive dust containing lead, antimony, and some arsenic, small amount of sulfur dioxide mist.	Waste battery acid, washdown water, runoff from breaker grounds and battery storage containing excess heavy metals.	Hard rubber (bakelite) with some adhering lead-bearing sludge.
Smelting and refining	Process waste gas emissions containing lead and trace amounts of antimony, arsenic, nickel, tin, copper, zinc and chlorine gas, sulfur dioxide, and carbon monoxide.	Slag granulator and wet scrubber wastewater, runoff from smelter grounds including raw material storage and slag piles containing excess heavy metals.	Slags, drosses, and skims; wet scrubber and water treatment plant sludges, vacuum flue, and washdown dusts.

SOURCE: MITRE Corp., 1980 and field interviews.

Treatment of wastewater typically involves pH adjustments and impoundment in tailings ponds for sufficient time to allow for the breakdown of organic reagents and settling of unrecovered solids (32, 42, 45). In more arid climates, where more complete water recovery is required, tailings slurry may be thickened and disposed of in storage areas and the water recycled. The amount of lead and associated metals and organic chemicals that may escape to surface waters is a function of: climate, water recycling, and water chemistry.

Smelting

Smelting of lead ore involves: (1) roasting in a sinter machine to drive off sulfur producing a lead-oxide rich sinter, (2) reduction of lead oxide to metallic lead in a blast furnace, and (3) various refining steps to remove trace metal impurities to produce lead bullion of a desired grade. A major environmental problem associated with the pyrometallurgical smelting process is the generation of large quantities of airborne particulates. Pollution control devices are employed to prevent emissions from reaching the atmosphere. Particulate pollution control systems commonly employed include fabric filters, wet scrubbers, and electrostatic precipitators.

Fabric filters consist of tubular bags of woven synthetic fabric or fiberglass. Exhaust gases are passed through the bags removing particulates by the filtering action of the fabric (38). Entrapped dust is removed by periodically shaking the bags or by injecting a high speed pulse of air, reversing the direction of air flow through the bags. Recovered dust is returned to the blast furnace for metal recovery. Fabric filters are the most widely used emission control devices at primary smelters. Collection efficiency is reported as greater than 99 percent. However, lower efficiency is normally achieved with dust particles and fume less than 2.5 microns in diameter (6, 47, 68).

Wet scrubbers collect particulates by means of high velocity water sprays, producing a multitude of water droplets impinging on particulates in the exhaust airstream, combining and removing the particulates in a dust-laden slurry. Wet scrubbers cool and humidify exhaust gas from the sinter machine prior to treatment in an acid plant. Collection efficiencies of up to 99.5 percent have been reported (38). Factors influencing efficiency include: particle size, particle density, liquid and gas turbulence, and liquid-to-gas ratio.

Electrostatic precipitators (ESP) remove particulates from the dust-laden gas stream by electrically charging dust particles and capturing them on grounded surfaces (38). A number of factors can lower ESP collection efficiencies, such as electrical resistivity of dust particles, particle size, and temperature and moisture content of the gas stream. Under optimum conditions, efficiencies can exceed 99 percent, but measured efficiencies may be considerably less under normal operating conditions (38).

Sintering

The sintering process is a major source of atmospheric particulate emissions in primary lead smelters. Chemical composition of the particulates varies considerably depending on characteristics of the ore, but range from

20-70 percent lead, 10-20 percent zinc, and 8-12 percent sulfur. Other trace elements contained within the ore mixture are volatized as oxides of arsenic, cadimum, copper, antimony, tin, selenium, bismuth, tellurium, silver, and gold. Particulate emissions can amount to over 215 kg/mt of lead produced, of which about 12 kg may be lead (38, 42, 48).

The sinter machine is the principal source of sulfur dioxide (SO_2) emissions from the primary smelter. Raw material fed to the sinter machine typically contains 13-19 percent sulfur. Approximately 85 percent is driven off as an oxide (37, 38, 39, 48, 49, 50). Although actual emissions of SO_2 vary considerably depending on the nature of raw materials and processing techniques, approximately 0.31 kg of SO_2 are generated per kilogram of lead produced (21).

Sinter offgases as a whole average less than 3 percent SO_2, too weak for use as feed to an acid plant. However, the gases can be divided into two streams, a strong stream collected at the front end of the machine averages 6 percent SO_2, and a weak stream formed at the rear of the machine containing 0.5 percent SO_2. The strong stream is sent to an acid plant for SO_2 recovery, whereas the weak stream is combined with the blast furnace offgases and treated for particulate recovery. Currently, all but one primary smelter practice some method of SO_2 control. The remaining smelter releases diluted SO_2 gas from a 600-foot stack under favorable weather conditions. Fugitive emissions of sulfur dioxide from the sinter machine released at transfer points and in the sinter crusher are considered minor (32, 37, 49). New Source Performance Standards as promulgated under the Clean Air Act require new sintering plants to employ weak gas recycling. This involves the recirculation of the weak gas stream through the sinter machine, thereby increasing SO_2 content of the sinter offgases. At present, one primary lead smelter in the U.S. employs this technique. Sinter offgases contain organic vapors resulting from incomplete volatilization of flotation reagents remaining in charge material.

The sinter machine does not directly produce liquid or solid waste. However, treatment of SO_2 emissions in an acid plant, produces such wastes which require proper handling. Inevitably, during the conversion of SO_2 to SO_3, and SO_3 to H_2SO_4, some loss of SO_3 occurs in the form of a fine acid mist estimated to amount to 0.02 to 0.04 kilograms SO_3 per metric ton of 100 percent acid produced. Additionally, 4 to 8 liters of off-grade weak acid are formed on the scrubbing column per 10 cubic meters of gas cleaned. The acid is neutralized, usually by limestone, and discharged to an impoundment lagoon. Impure gypsum, formed by the neutralization of the acid, constitutes a solid waste (42, 49).

Blast Furnace

The blast furnace is a major source of atmospheric emissions from a primary smelter. The amount of particulates generated by the blast furnace depends upon furnace size, operating procedures, efficiency, and material throughput. Estimates range from 87 to 180 kilograms of uncontrolled particulate per metric ton of bullion produced. Particulates consist of 10-40 percent lead, resulting in 8.7-72 kilograms per metric ton of bullion. Trace elements volatilized in the furnace are entrained in exhaust dust and fumes as oxides and sulfates of zinc, cadmium, copper, antimony, arsenic, selenium, tellurium, chlorine, fluorine, indium, tantalum, gold, and silver (37, 38, 42, 48).

Most of the sulfur remaining in the sinter and furnace fuel is contained in slag discharged from the furnace bottom. Exhaust gas is reported to contain only 0.01 to 0.25 percent SO_2 after dilution with ventilation air.

Combustion of the furnace fuel charge generates large amounts of carbon monoxide. Prior to dilution, the carbon monoxide comprises 25-50 percent of the flue gas. Dilution with fresh air at the top of the furnace changes a large percentage of the carbon monoxide to carbon dioxide and serves to cool the exhaust gas prior to baghouse treatment.

The principal solid waste product of the blast furnace is formed by the interaction of metallic impurities in the sinter with the flux charge. This interaction forms a slag composed primarily of iron and calcium silicates. The composition of the ore determines the metals that may be present in the slag. Slag remaining after economically recoverable minerals have been removed constitutes a solid waste. Before solidification, molten slag is granulated by a water spray to facilitate handling. This material is conveyed in slurry form to a dump or tailing pond. In general, disposal of slags causes few problems, since metals present are tightly bound within the slag's siliceous matrix. However, water used for granulation may acquire environmentally unacceptable levels of metals requiring treatment in impoundment lagoons. After the metal content of the water is lowered to acceptable levels, the water is either recycled to the granulator or released to surface waters (31, 38).

Drossing and Refining

Drossing is generally conducted in close proximity to the blast furnace using either or both a dross reverberatory furnace and dross kettles. The process removes byproduct metals, primarily copper and arsenic, from molten lead bullion. Approximately 10 kilograms of particulate emissions per metric ton of lead are produced. Lead content is estimated to range between 13-35 percent of total particulate emissions, resulting in 1.3-3.5 kg per metric ton of lead produced. Emissions may contain volatilized trace metals depending upon the complexity of ore. Sulfur added to the bullion during drossing to precipitate copper sulfide (CuS_2) dross may contribute a small amount (less than 0.05 percent by volume) of SO_2 to emissions (37, 38, 42).

Dross reverberatory emissions are similiar to those generated during drossing in kettles. Considerable carbon monoxide emissions are generated due to the reducing conditions and coke contained in the fuel charge. Sulfur dioxide comprises only 0.05 percent by volume of the waste gas (38, 50). Refining practices are largely governed by the characteristics of the specific ore. Western ores, more complex than Missouri ores, require a more complex refining process. Emission volumes generated during refining are much less than during sintering or blast furnace reduction (56, 57). Of primary concern are lead, arsenic, cadmium, antimony, and zinc-bearing dust and fume aerosols contained in offgases (74). Byproduct treatment in reverberatory and cupola furnaces, and small retorts contributes to the lead refining emissions. Although the volume of byproduct materials is low, higher temperatures are employed promoting increased metal volatilization.

Secondary Lead Industry Sources

Primarily, the secondary lead industry employs blast furnaces but to a lesser extent reverberatory and rotary furnaces for the process of refining lead scrap. Scrap lead constitutes over 60 percent of raw material for secondary lead facilities. Emissions from the secondary industry are to a large degree dependent upon raw material feed. Varying proportions of lead sulfide (PbS). Sulfur dioxide (SO_2), lead oxide (PbO), and elemental lead (Pb) are emitted from secondary industry operations. In addition, chlorine emissions may reach relatively high levels of concentration, resulting from combustion of battery casings and separator plates made of polyvinylchloride (PVC). However, only about three percent of U.S. automobile batteries use PVC (57, 58, 67, 68).

Differences in furnace operation may also contribute to variations in composition of baghouse dust. Relatively high blast furnace temperatures produce an abundance of elemental lead in the baghouse (67, 68). Emissions may also contain trace amounts of antimony, arsenic, nickel, tin, copper, and zinc. Fuel used in the furnace contributes fumes and particulates of smoke, sulfur, oil, carbon monoxide, limestone, fuel bits, and coke dust (7, 12).

According to EPA (57), for every metric ton of lead produced by the secondary lead industry approximately 23 kilograms of lead emissions are generated. Estimations of collection efficiency of emission control devices vary slightly, usually given to be upwards of 99.0 percent efficiency. Emission control devices include fabric filters and wet scrubbers, balloon flues, dropout chambers, water spray towers, and hair pin air coolers. Efficiency is closely related to size of particles, with efficiency decreasing as particle size reaches less than 2.5 microns. However, about 70 percent of escaping particulates consist of particulates less than 2.5 microns in diameter. Total collection efficiency of over 99 percent reduces daily stack emission production of 8,000 kg/day to 7 kg/day, for a typical secondary smelter.

Sulfur oxides, primarily sulfur dioxide, are generated by combustion of sulfuric acid from batteries, and to a much lesser extent from sulfur contained in the fuel charge. Data presented by EPA (57) indicates smelting of 1 ton of lead in a blast furnace results in 76 pounds of sulfur dioxide. Smelting of 1 metric ton of lead in a reverberatory furnace results in 47 kilograms of sulfur dioxide. The difference is due to higher temperatures of the reverberatory furnace and the presence of iron flux in the blast furnace charge.

As in primary smelters, fugitive emissions emanating from secondary smelters are thought to be the major contributor to lead in air and soil in the vicinity of the plant (77, 76). Fugitive emissions may originate from virtually all processes in the secondary smelting industry. Major contributors include battery breaking, storage and handling of baghouse flue dust, and raw material from molten metal transfer points (57, 70, 71). Comprehensive estimates of fugitive emissions range from a low of 0.2 kg/mt (70) up to a high of 13.5 kg/mt (11).

CHAPTER 3. — THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION'S (OSHA) LEAD STANDARD

A. REQUIREMENTS OF THE CURRENT OSHA STANDARD

For purposes of this study, "the current OSHA standard" refers to the standard published in the Federal Register on November 14, 1978 (43 FR 52952). A draft revision was proposed in March 1983; however, that proposal was abandoned in favor of individual compliance plans.

The current OSHA standard indicates the following priorities on methods of control: (1) engineering, work practice and administrative controls; and (2) personal protection equipment. Rationale, to an extent, appears based on the following (43 FR 52990, 55):

> "One is that protection of the employee is most effectively attained by elimination or minimization of the hazard at its source, which work practices and engineering controls are both designed to do, and the other is that methods which depend upon the vagaries of human behavior are inherently less reliable than well-maintained mechanical methods...
>
> "Engineering control is unquestionably the best method for effective and reliable control of employee exposure to lead... It acts on the source of the emission and eliminates or reduces employee exposure without reliance on the employee to take self-protective action...
>
> "...Work practices also act on the source of the emission, but rely upon employee behavior, which in turn relies upon supervision, motivation, and education to make them effective. For this reason, work practices are not as desirable a method as engineering controls, but because the two methods often must be employed together to make either one effective...and because they are the only methods that act to eliminate or reduce the hazard at its source, they have been given equal status in the compliance priorities of the final lead standard.
>
> "Respiratory protection is relegated to the bottom of the compliance priority list because it is an ineffective, unreliable, and unsafe method of reducing employee exposure...respirators are not comparable alternatives to engineering controls, work practices, and administrative controls because they do not eliminate the source of the exposure, are generally not capable of providing the protection required, and create additional hazards by interfering with vision, hearing and mobility...
>
> "...The OSH Act places the primary burden of compliance on the employer, and to shift it to the employee, as respirators do, is, according to National Institute for Occupational Safety and Health (NIOSH), inappropriate ...and is contrary to established OSHA policy."

A key requirement of the OSHA standard states that respirators are used to supplement engineering controls. The exposure levels for the periods during which the respirator is worn may be averaged with exposure levels for periods in which the respirator is not worn to determine daily time-weighted average (TWA) exposure for the employee (55). When engineering controls are not deemed feasible for achieving the Permissible Exposure Limits (PEL) respirators may be worn to bring the employees TWA exposure down to the PEL.

In deriving the basis for air and blood lead standards, OSHA relied on a physiological model originally developed by S. R. Bernard for the Center for Policy Alternatives (55). The model is based on the assumption of a relationship between air lead concentrations and average blood lead (PbB) levels within a population. The higher the air lead concentrations the greater the likelihood of inhalation and ingestion of lead particles by the population exposed and the greater the likelihood of elevated PbB levels within that population.

Action Level and Monitoring Requirements

The "action level" is defined as an employee exposure, without regard to the use of respirators, to an airborne concentration of lead of 30 $\mu g/m^3$ averaged over an 8-hour period. Whenever exposure monitoring is discussed under the standard, exposure is defined as "that exposure which would occur if the employee were not using a respirator." Employers covered by the lead standard must make an "initial determination" whether their employees are exposed to lead at levels above the action level. If they are not above the action level, the employer must write a "negative initial determination" that includes: (1) information indicating that employees are exposed to lead, (2) employee complaints of symptoms indicating exposure to lead, and (3) airborne lead measurements made during the preceding year.

When an employer issues a "positive initial determination" that an employee may be exposed at or above the action level, the employer must conduct full shift (for at least 7 continuous hours) personal sample monitoring "representative of the exposure for each employee" and include "at least one sample for each shift for each job classification in each work area." If the individual exposure is above the action level but below the PEL, monitoring must be repeated every six months. Monitoring must be repeated until at least two consecutive measurements, taken at least seven days apart, are below 30 $\mu g/m^3$.

If an individual employee exposure is above the PEL, monitoring must repeated quarterly. Once two consecutive measurements, taken at least seven days apart, are below the PEL, monitoring must continue as described in the preceding paragraph. The employer must also conduct additional monitoring if there is reason to believe that there is additional exposure to lead.

Engineering and Work Practice Controls

The implementation schedule to satisfy the engineering and work practice control provisions of the standard for the three lead-industry sectors considered is presented in Table 3-1. All sectors were to comply with a 200 $\mu g/m^3$ standard on the effective date, February 1, 1979, but the primary sector was given 10 years to comply with the 50 $\mu g/m^3$ PEL, as compared to 5 years for secondary and battery sectors.

Table 3-1. - Implementation Schedule

Industry 1/	Compliance Date 2/		
	200 $\mu g/m^3$	100 $\mu g/m^3$	50 $\mu g/m^3$
Primary lead production	3/	3	10
Secondary lead production	3/	3	5
Lead-acid battery manufacturing	3/	3	5

1/ Includes ancillary activities located on the same site.

2/ Stated as the number of years from the effective date by which compliance with the given air lead exposure, expressed as an 8-hour TWA, must be achieved.

3/ Must be achieved on the effective date of February 1, 1979, by promulgation of November 14, 1978, but stayed by court orders until June 29, 1982.

Source: Reference 55.

Personnel Protection

A written compliance program by the employer is required to reduce exposure levels below the PEL, solely by engineering and work practice controls. In accordance with the implementation schedule, the program must include the following: (1) a description of each operation that emits lead, including machinery used, material processed, controls in place, crew size, employee job descriptions, and operating and maintenance procedures; (2) a description of the means to reach compliance, including engineering plans and studies; (3) the technology considered for achieving the PEL; (4) air monitoring data; (5) a detailed schedule of implementation; and (6) a work practice program with administrative controls. The compliance program must be maintained at the worksite for examination and copying by affected employees.

The standard states that during the period necessary to implement engineering controls, except during the compliance period for the interim standards of 200 and 100 $\mu g/m^3$, the operator shall not require a worker to wear a respirator longer than 4.4 hours per day. Respirators are to be worn when engineering or work practice controls cannot reduce exposures to 50 $\mu g/m^3$, or at the employee's request.

Specifications for various levels of respirator protection against lead aerosols, dust, fume, and mist as approved by the Mine Safety and Health Administration (MSHA) and the National Institute for Occupational Safety and Health (NIOSH) are established under 30 CFR Part 11.

Employers will perform quantitative or qualitative fit testing for employee respirators, as required under amendments to the OSHA standard (58, 59). Fit testing is designed to ensure that the employee is attaining full protection from the respirator. Employers are required to institute a respirator program under the provisions of 29 CFR 2920.134 (b), (d), (e), and (f).

Operators are required to provide protective clothing for employees. Protective clothing must be cleaned weekly, and daily for employees exposed to air lead levels above 200 $\mu g/m^3$ for an 8-hour TWA. Clothes are to be changed in a special change room equipped with separate storage areas. Workers are required to shower at the end of the work shift and clothing or equipment worn during the shift must remain on site. This requirement helps prevent lead workers from carrying dust home. Contaminated protective clothing is to be deposited in a closed container. Laundry instructions are to include an admonition to dispose of contaminated wash water in accordance with local, State, and Federal regulations.

Under general housekeeping provisions, workplace surfaces are to be kept as free as practicable from lead accumulations. Vacuuming is the preferred method. Compressed air may not be used to clean surfaces; and shovelling and sweeping may be used only after vacuuming has been demonstrated ineffective. Several primary operators use washdown methods as dust from lead ores are often difficult to remove by vacuuming.

Medical surveillance, without cost to employees, is required for employees exposed to lead above the action level for more than 30 days per year. Examinations must be performed by or under the supervision of a licensed physician. Examinations shall be: (1) at least annually for each employee who had a PbB at or above 40 $\mu g/100g$ during the preceding 12 months; (2) prior to employee's assignment to a work area with air lead levels higher than 30 $\mu g/m^3$; (3) for an employee showing symptoms of lead intoxication or difficulty in breathing through a respirator; and (4) and as deemed medically appropriate. Biological monitoring, including PbB and zinc protoporphyrin sampling and analysis, is required (1) at least every 6 months for each employee exposed above the action level for more than 30 days per year; (2) at least every 2 months for workers having PbB levels higher than 40 $\mu g/100g$, and (3) at least monthly during the period that any worker is on medical removal due to high PbB levels. Employees are to be notified of monitoring results within five working days. Written notification is required to be given to employees whose PbB levels exceed 40 $\mu g/100g$ or whose PbB levels exceed the criterion for medical removal protection.

The employer selects the initial examining physician while the employee may designate a second physician to review the initial physician's finding and conduct additional examinations the second physician deems necessary. The employer must notify the employee of this right after examination by the initial physician. The employer may condition his participation in and payment for the multiple review process.

The employee will receive copies of the medical opinions including (1) the medical condition that may result in increased health risk, (2) the additional protective measures deemed necessary, (3) the recommended use of a powered air purifying respirator instead of a negative pressure respirator and (4) PbB levels.

Medical Removal Protection (MRP)

Medical removal protection is required for workers with elevated PbB levels that are considered to endanger their health. Because of potential economic hardship that could be inflicted upon industry and worker if MRP requirements were suddenly introduced, OSHA phased in the requirements over a five-year period. Activation of the MRP provisions is commonly referred to as the "trigger mechanism" usually expressed as two numbers separated by a slash. The first number designates the PbB level at which the employee will be removed from the workplace under MRP. The second number designates the PbB level at which the employee may be returned to his customary job.

The MRP triggers were implemented as follows:

(1) June 29, 1981 [1]: 80/60 for those employees exposed to air lead concentrations at or exceeding 100 $\mu g/m^3$ for an 8-hour TWA.

(2) June 29, 1981 [1]: 70/50 for those employees exposed to air lead concentrations at or exceeding 50 $\mu g/m^3$ for an 8-hour TWA.

(3) June 29, 1981 [1]: 60/40 (or an average PbB level over 50 $\mu g/100g$) for those employees exposed above the action level.

(4) March 1, 1983: 50/40. In this case, the trigger comes into effect only after the average of the last three blood samples (or the average of all).

The employee must be provided with up to 18 months of MRP benefits on each occasion the employee is placed under MRP. The employer must maintain the employee's earnings, seniority, and other rights or benefits. The employer may condition the provision of MRP benefits upon the employee's participation in follow-up medical surveillance.

If an employee's PbB levels do not decline to the return level within the 18-month MRP benefits period, the employer is required to:

(1) make a medical examination available to the employee to obtain a final medical determination; the final determination indicates whether the worker can be returned to the former job and, if not, specifies measures necessary to protect the employee's health;

(2) continue to provide MRP benefits to the employee either until the employee can be returned to former job status or until a final medical determination indicates that the employee is incapable of ever being safely returned to the job.

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[1] Originally February 1, 1979, but postponed by court order until this date. Other phases similarly delayed from March 1, 1980, and March 2, 1981.

Final medical determination may indicate that the employee can be returned to his former job in despite of a normally unacceptable PbB level. After such a determination, the operator need not automatically remove the employee under PbB removal criteria. However, the employee could be removed in the future under a subsequent medical determination. Rationale behind the provision is that the damage done to the employee's health may be beyond correction. Therefore, the employee's physician may permit return to the job provided that the worker's PbB level remains relatively constant.

The operator must provide annual training for the employee exposed above the action level of 30 $\mu g/m^3$. Such training must include:

(1) the OSHA standard and appendices;

(2) the nature of operations resulting in lead exposure and the adverse health effects of lead;

(3) the purpose and limitations of respirators;

(4) the medical surveillance program and the engineering and work practice controls associated with the job; and

(5) a warning concerning the use of chelating agents to lower PbB.

Variance Procedures

Under the Occupational Safety and Health Act of 1970 and its implementing regulations in 29 CFR, Part 1905, operators may apply for either temporary or permanent variances to the OSHA standard. OSHA will, during the variance review process, "take individual claims of infeasibility into account through abatement programs tailored to meet the needs of individual firms and their employees" (55).

Temporary variances may be sought under section 6(b)(6)(A) of the act for cases in which an employer needs additional time to meet a compliance schedule. A permanent variance may be sought under section 6(d) of the act by employers who have developed alternative processes or practices which are as "safe and healthful" as those required by an OSHA standard. For either type of variance application, OSHA may issue an interim order allowing the employer to continue to operate pending final OSHA approval or denial of the variance application. In either case, the employer is to use all available means to protect employees from hazards covered by a standard and to notify employees of the status of the variance application.

B. PROBLEMS ATTAINING THE 50 $\mu g/m^3$ PEL BY ENGINEERING CONTROLS

In the 1978 notice of final rulemaking for the OSHA lead standard, OSHA acknowledged that "a PEL of 50 $\mu g/m^3$ will not achieve the goal of maintaining the PbB in all occupationally exposed workers below 40 $\mu g/100g$" (55). However, the agency used the S. R. Barnard model, as adapted by the Center for Policy Alternatives, to predict the PbB concentrations of lead-exposed workers if uniform compliance with a 50 µg/m^3 PEL were achieved. The agency considered nonferrous foundries, lead pigment manufacturing, and other industries in addition to the primary lead, secondary lead, and battery producing sectors. OSHA arrived at PbB level predictions and compared them to PbB levels recorded for all lead exposed workers in 1978. Comparisons are shown in Table 3-2.

Table 3-2.-Bernard Model Predictions of Worker PbB Levels
Based on Achieving the 50 µg/m^3 PEL, Compared to
Historical Worker PbB Levels in 1978

(Expressed as percentages of the workforce at various PbB levels)

PbB Levels	Bernard Model Prediction	1978 Actual[1/]
Exceeding 60 µg/100g	0.5	22.4
50 - 60 µg/100g	5.5	32.6
40 - 50 µg/100g	23.3	38.7
Total Above 40 µg/100g	29.3	83.8

1/ Assumes compliance with 200 µg/m^3
Source: Reference 55, p. 52963.

Table 3-2 shows that if the 50 µg/m^3 PEL were fully achievable, a substantial portion of the lead industry workforce would still have PbB levels above 40 µg/100g. Moreover, PbB levels indicated for both the Bernard Model predictions and the 1978 historical columns may be lower than would be encountered if only workers in the primary lead, secondary lead and battery producing sectors had been considered. Highest exposures are normally found in these sectors.

In 1981, OSHA contracted with Charles River Associates (CRA) to conduct a regulatory impact analysis of the effects of the OSHA lead standard on the primary lead, secondary lead, and battery producing sectors (6). CRA performed an extensive survey of air lead levels and employee PbB levels in primary and secondary smelters and battery manufacturing plants.

The survey indicated that in 1982 about 80 percent of the workforce in primary lead smelting was exposed to greater than a maximum 8-hour TWA of 50 µg/m^3 air concentration. Moreover, close to 45 percent of the workforce was exposed to concentrations in excess of 200 µg/m^3. CRA noted that; "While additional controls are feasible for many operations, even 90 percent reductions in existing emissions would not achieve compliance with the existing 50 µg/m^3 PEL standard in most areas of primary lead smelters." (6). This is particularly apparent in sinter plant areas, where average concentrations exceed 1,000 µg/m^3 many times over for an 8-hour TWA, and in blast furnace and dross plant areas where peak exposures often exceed 1,000 µg/m^3. CRA explained that since 1979, primary smelter operators have enforced their respirator programs.

Consequently, employee PbB levels lowered significantly. For example, whereas 27 percent of the workforce in the primary sector had PbB levels in excess of 60 µg/100ml in 1979, only 4.7 percent of the current exposed workforce has such high PbB levels (6).

The percentage of the secondary smelting workforce exposed to average air lead concentrations in excess of the 50 $\mu g/m^3$ PEL was about 76 percent in 1982. About 42 percent of the workforce was exposed to concentrations in excess of 200 $\mu g/m^3$, and over 50 percent was exposed to concentrations above 150 $\mu g/m^3$. CRA noted that for 18 secondary facilities sampled, about 7 percent of the workforce had PbB levels in excess of 60 µg/ml (6). Battery production exposed workers to air lead concentrations in excess of the 50 $\mu g/m^3$ PEL. Operations frequently exposed workers to air lead levels above 200 $\mu g/m^3$. Over 68 percent of employees at small battery plants were exposed to concentrations in excess of 50 $\mu g/m^3$ in 1982. However, at larger battery plants only 37 percent of the workforce was exposed to air lead levels in excess of the PEL. Thus, for the battery industry as a whole, nearly 34 percent of all workers were exposed to air lead concentrations below 30 $\mu g/m^3$.

Only 2.1 percent of the battery industry workforce had PbB levels exceeding 60 µg/100ml.[1/] Roughly 83 percent of exposed employees were under 50 µg/100ml, and about 43 percent were lower than 40 µg/100ml (6).

Percentages of lead-exposed employees exhibiting PbB levels in 1982 above 60 µg/100ml were as follows: primary lead, 4.7 percent; secondary lead, 7.7 percent; and battery manufacturing, 2.1 percent. Note the reduction in numbers compared to the historical data in Table 3-2 indicating that in 1978 over 22 percent of all lead-exposed workers had PbB levels exceeding 60 µg/100g. This "substantial improvement in the distribution of blood-lead levels" was attributed to "improved hygiene and respirator programs" (6).

Brunswick Mining and Smelting Corporation, Ltd., of New Brunswick, Canada presented a report at the 1983 Lead Industry Association's annual meeting that recounted the efforts made to reduce PbB levels in workers at the company's Belledune primary lead smelter from 1966 to 1983. This facility is similar to domestic primary lead smelters in Missouri. Although the company spent $15 million during this period to reduce worker lead exposure, in no area of the Belledune plant did the company achieve the OSHA 50 $\mu g/m^3$ PEL. However, from 1976 to 1982, the firm succeeded in reducing the employees average PbB levels from 59.4 µg/100ml to 37.3 µg/100ml.

The experience of Brunswick Mining and Smelting Corporation, Ltd., could be anticipated for other firms. CRA conducted engineering cost analyses and employee exposure projections for two secondary and two primary lead smelters. These analyses assessed the feasibility of compliance with two PEL's: (1) a 50 $\mu g/m^3$ maximum 8-hour TWA PEL, and (2) a 150 $\mu g/m^3$ maximum 8-hour TWA PEL.

[1/] For purposes of measuring PbB levels, 100 milliliters (100ml) is nearly equivalent to 100 grams (100g). There are cases in which the difference is important, but they will not be considered in this discussion.

CRA's findings indicate that the 50 $\mu g/m^3$ engineering limitation or PEL without the use of respirators is infeasible with currently demonstrated technology.

In March 1983, the OSHA published a Draft Lead Standard Proposal that would have revised the original 1978 OSHA Lead Standard (60). The draft proposal acknowledged that technologies commonly believed to make the 50 $\mu g/m^3$ PEL achievable in the primary and secondary sectors would not be technically or economically practicable in attaining the 50 $\mu g/m^3$ goal (60). Also, the agency recognized that "respirators appear to have contributed substantially to the reduction of blood lead levels since 1979." The draft OSHA proposal contained three elements not previously recognized in the 1978 regulation:

1. An "engineering control average limit" (ECAL) of 150 $\mu g/m^3$ maximum allowable 8-hour time-weighted average (TWA) exposure "that must be achieved, where feasible, by engineering, work practice, and administrative controls" (60). This ECAL indicates the limitations of currently demonstrated technology.

2. A 50 $\mu g/m^3$ PEL to be achieved by a combination of methods including respirators.

3. The current limitation of 4.4 hours per day on the use of negative pressure respirators by employees "does not contribute to, and may in some cases hinder, the protection of employee health" (60). Consequently, the proposal deleted the current restriction on the number of hours that an employer may require employees to wear negative pressure respirators.

After OSHA released the March 1983 proposal, a decision was made within the agency not to proceed with the new technical requirements. Since recision of the proposal, OSHA has advocated the establishment of tripartite commissions on a company-by-company or plant-by-plant basis to determine the necessary engineering controls for each facility. Under each tripartite agreement, the company, the union, and OSHA would cooperatively define "feasible" engineering controls to be implemented at each facility.

Safer lead industry technology may require a longer timeframe to develop. Currently emerging technologies have not been fully demonstrated on a commercial scale. At this time, such technologies have only operated at a reduced capacity or intermittently under pilot testing. Many of these technologies have not been fully evaluated for their suitability for various feed stocks, nor for byproduct recovery.

C. MEDICAL REMOVAL PROTECTION COMPLIANCE PROBLEMS

During field interviews, industry representatives often expressed concern about their companies' ability to comply with the MRP. As of March 1, 1983, an employee could be placed on MRP under either of the following conditions:

(1) two consecutive PbB levels above 60 μg/100g of whole blood.

(2) the last three PbB samples have an average above 50 μg/100g of whole blood, or the average of all blood sampling tests for the preceding 6 months, whichever is longer, indicate that the PbB level is above 50 μg/100g. (Except that the employee need not be removed under MRP if the last PbB level is at or below 40 μg/100g.)

Once on MRP, two consecutive PbB tests below 40 μg/100g are required to return the employee to his customary job. Until that time, the employee is entitled to up to 18 months of MRP benefits.

On February 28, 1983, temporary variances were issued to 45 companies that had applied for a variance to the 60/40 removal and return triggers during 1981. After that time, the 50/40 trigger would go into effect. Companies not able to comply with that standard would have to make another application to OSHA for a 50/40 variance. Any company receiving such a variance would continue to operate under an interim order defining OSHA's terms for granting the variance.

The following discussion only addresses the OSHA grant of the temporary variances mentioned above. In the notice, OSHA acknowledged the issue of compliance feasibility with the 60/40 MRP triggers on a plant-by-plant basis. For example, many employees for the 45 plants requesting variances had PbB levels in the 60-70 ug/100g range. PbB levels at these plants, during July 1980 through July 1981, showed that MRP removals would range from 10 to 66 percent of the skilled workforce.

Supervisory and maintenance personnel tended to have higher PbB levels for two probable reasons. First, such personnel generally had more years of experience in the industry and their tenure dated back to times of less stringent environmental and health and safety controls. Consequently, they had relatively larger lead body burdens resulting in high PbB levels. Second, supervisory and maintenance workers were likely to be involved in corrective operations when pollution control or production equipment fails, resulting in "upset" conditions. During upset conditions, usually much higher concentrations of particulate lead are in the air because repair work commonly results in disturbance and suspension of lead particles.

These factors seem evident in some data OSHA reported in its variance notice. For example, OSHA stated that six plants had a high percentage of their experienced supervisors with PbB levels above 60 μg/100g, as follows (48 FR 4065):

Mule Emergency Lighting, Inc.	1 of 1
ILCO, Inc.	9 of 9
Inland Metals Refining Company	3 of 4
Gould Incorporated, Frisco, Texas	3 of 4
Taracorp Industries (McCormick Plant	4 of 6
Seitzinger Lead Smelters and Refiners	8 of 15

OSHA cited similar data for highly skilled maintenance employees at four plants. OSHA reported: "Thirty-four employers claim that the removal of the supervisory, maintenance and highly skilled employees would be prolonged beyond OSHA's original expectation in order for their blood-lead levels to drop to the 40 μg/100g return level" (63). Companies had estimated that 18 to 36 months would be required for the removed employees' PbB levels to drop from between 60-70 μg/100g to the 40 μg/100g level, but the companies "provided no data to support their estimate." (63).

In the variance notice, OSHA restated the position of several companies concerning the implicit costs of temporarily losing experienced employees. For example, OSHA cited Amax's contention that temporary replacement of skilled supervisory, maintenance, and production employees is "virtually impossible." The company cited such factors as experience and training requirements for the operation personnel (63).

OSHA also cited ASARCO's apprenticeship program that requires four years of apprenticeship for each craft in the smelting process. Moreover, the replacements for supervisory personnel removed on MRP may come from the hourly workforce. According to OSHA, ASARCO maintained that these workers' acceptance of a temporary supervisory position (for only the duration of the incumbent's removal on MRP) would involve their: (1) resignation of union membership, (2) loss of union benefits, and (3) jeopardization of seniority and pension rights (63).

The OSHA notice repeated the comments of General Battery Corporation that the supervisors and skilled workers most likely to be removed under MRP would be those most responsible for enforcement of safety, health, and environmental regulations within the plant. In some cases, the danger posed by the absence of such employees could be extreme (63).

As a result of variance applications received concerning the 60/40 MRP triggers, OSHA concluded:

(1) Roughly 10 percent of the lead-exposed workforce for those plants granted variances would be on "continuous temporary medical removal at the 60 μg/100g removal trigger." But, removal of 10 percent of the skilled workforce at each plant "would affect the ability of each plant to continue to operate."

(2) Firm conclusions could not be drawn about the length of time required for a removed employee's PbB level to drop to 40 μg/100g. But, the time necessary to train competent replacement employees for those on medical removal could be: 6 to 18 months for supervisors; 1 to 3 years for maintenance personnel; and 3 to 16 months for skilled production employees." Estimates were not made concerning costs incurred in removing 10 percent or more of the workforce under MRP.

(3) "Based on the air-lead data, the number of available positions located in areas below the 30 $\mu g/m^3$ action level are inadequate to accommodate the numbers of employees placed on MRP because of elevated bloodleads."

D. GENERAL CONCLUSIONS

1. Increased emphasis on health and safety education for coworkers would help to complement engineering controls, which will take time to develop and fully implement (6, 56, 57, 58).

2. To achieve the OSHA 50 $\mu g/m^3$ PEL solely by engineering controls may be infeasible with currently demonstrated technology. It may remain technically infeasible for a considerably longer time than the compliance deadlines of 10 years for primary smelters and 5 years for secondary smelters and battery plants.

3. Since promulgation of the current OSHA Lead Standard in 1978, major gains in lowering employee PbB levels apparently have resulted from respirator and hygiene programs.

4. The potential impact of the current MRP regulations provides a strong incentive for lead industry operators to concentrate on lowering employee PbB levels.

Chapter 4. - NATIONAL AMBIENT AIR QUALITY STANDARD FOR LEAD AND RELATED ISSUES UNDER THE CLEAN AIR ACT

A. THE CLEAN AIR ACT FRAMEWORK AND LEAD REGULATION

The Clean Air Act (CAA) as first passed in 1963 (PL 88-206) indicated that the States had the responsibility for setting and achieving air quality standards with Federal financial and advisory assistance. A succession of amendments, particularly in 1970 (PL 91-604) and 1977 (PL 95-294), reinforced the Federal authority over State programs by setting national standards and requiring Federal approval of State air pollution control programs (64). Failure to attain Federal approval could ultimately result in curtailment of Federal funds for such programs as new highway construction.

The principal provisions of the CAA as amended in 1977 include responsibilities for both Federal and State authorities. The Environmental Protection Agency (EPA) is charged with identifying emissions that may endanger public health or welfare, with setting primary and secondary emission National Ambient Air Quality Standards (NAAQS) for these pollutants, and with controlling emissions from new or newly modified stationary sources (under new source performance standards or NSPS) and from motor vehicles. States are required to submit State implementation plans (SIPs) for the attainment of NAAQS within nine months after their promulgation for each air quality region. These plans are subject to approval by the EPA. EPA may prepare a plan for a State that fails to issue one. State discretion is further restricted by Federally imposed obligations (1) to take steps to prevent significant deterioration (PSD) of air quality in regions already attaining NAAQS, 2) to prescribe certain control technology for new or modified stationary sources; and 3) in nonattainment areas, to inventory and quantify emissions from all sources and direct remedies in nonattainment areas. Finally, the Federal Government may enforce State plans if the State fails to enforce their provisions.

Ambient air lead is one of the seven pollutants for which NAAQS have been established. The National Academy of Sciences publication, "Airborne Lead in Perspective," did not provide, in EPA's judgment, sufficient basis for identification of an ambient air lead standard (65). EPA regulated air lead by relying on Section 211 in the CAA pertaining to reduction of automotive fuel additives. EPA estimated, for example, that 87.7 percent of the annual atmospheric lead emissions for the U.S. during 1975 came from gasoline combustion in mobile sources (24). Near lead plants, as would be expected, automobiles are not such a dominant source of air lead.

A Natural Resources Defense Council (NRDC) suit resulted in a court order in 1976 requiring EPA to set a NAAQS for lead. That step, taken in October 1978, required SIPs for air lead, thus extending control of lead emissions to industrial sources. Another NRDC suit, settled out of court by an agreement with EPA in July 1983, may impose Federal lead plans on as many as 17 states with lead smelting and refining facilities that do not comply with the 1978 rule (66). SIPs are required by the CAA to specify a strategy for implementing, attaining, maintaining, and enforcing the NAAQS in each of the

247 air quality control regions. The July 1983 settlement agreement envisioned all lead SIPs being filed by August 1, 1984. The CAA holds that compliance dates are to come within three years after plan approval unless extensions are granted, as they have been in the case of Missouri, for example (68).

B. THE FORMULATION OF THE 1.5 µG/M^3 EPA AIR LEAD STANDARD

The NAAQS for lead compounds is 1.5 micrograms per cubic meter (1.5 µg Pb/m^3), the maximum arithmetic mean averaged over a calendar quarter. To estimate this concentration of lead in the air that is ruled to pose an unacceptable risk to health, EPA made four key judgments (69). First, a "sensitive population," i.e., population subgroup which has the lowest threshold for adverse effects or greatest potential for exposure, was selected. For lead, that group was deemed to be young children aged 1 to 5. Second, a safe level of lead exposure including an adequate margin of safety was established. EPA concluded that the maximum safe level for an individual child is 30 micrograms of lead per deciliter (30 µg Pb/dl) of blood, while the geometric mean for the population PbB would have to be put at 15 µg Pb/dl in order to place 99.5% of the sensitive group below 30 µg Pb/dl. Third, a portion of PbB contributed by nonair sources had to be deleted from the acceptable blood level average. EPA stated that 12 µg Pb/dl of the population PbB for children should be attributed to nonair exposure, leaving air's contribution at no more than that necessary to produce 3 µg Pb/dl of blood. Fourth, the relationship between air lead and PbB had to be determined. EPA judged that relationship to be 1 to 2, yielding an ambient air standard for lead of 1.5 µg Pb/m^3 of air.

The Federal Register notice that promulgated the lead NAAQS (69) stated that EPA's own economic impact assessment indicated "nonferrous smelters may have great difficulty in achieving lead air quality levels consistent with the proposed standard in areas immediately adjacent the smelter complex" (69). EPA changed the averaging period from one month to one quarter, theoretically allowing a greater number of brief concentrations in excess of 1.5 µg Pb/m^3 to occur without violation of the standard. Also, EPA noted that States have the primary role in developing attainment requirements and that until they do EPA could not adequately judge feasibility (69). Since most States having major lead facilities do not yet have approved SIPs and others have been granted attainment extensions, it is premature to judge whether the standards will be attainable.

Technical and Economic Feasibility

Controversy exists centering on the technical feasibility of a 1.5 µg standard for particulate lead at the plant fenceline. The lead industry maintains that preliminary testimony and engineering analyses indicate that, at best, only a 5 µg Pb/m^3 standard could be achieved using current control technology. An industry study indicated that the major obstacle to technical achievement of the 1.5 µg lead standard was "high background levels of resuspended lead particulate matter" (68). To control resuspended fugitive dust, operators are engaged in a program to pave and vegetate or apply soil binders to smelter and battery plant grounds. Virtually all of the facilities visited for the study were in various stages of concreting or they were planning to concrete work areas as budgets permitted. This would facilitate vacuuming or washing down of particulates before they get resuspended.

Washdown appears preferable to vacuuming because washdown removes heavy lead particles more efficiently and wet particles are more difficult to resuspend. Washdown is probably only feasible for larger-area plants with open building construction that have room to install and operate settling facilities to minimize external discharge of contaminated water. Washdown was used on a plant-wide scale at only one primary facility visited. Some primary and many secondary operators rely mainly on vacuuming because of plant geometry and the acreage needed for washdown facilities. Forced reliance on a less efficient method for controlling fugitive lead dust would probably be difficult for smaller facilities to comply with in order to meet the NAAQS for lead.

Ambient air quality standards related to a human health criterion is based on the assumption that pollutants in excess of the standards around a given plant automatically carry a degree of human risk that outweighs any other economic, sociological, or technical consideration. A site-specific compliance determination may be more reliable because of modelling imprecision and restrictive assumptions in the risk calculations for a general standard (95,96).

C. OTHER AIR REGULATORY CHANGES THAT MAY IMPACT THE LEAD INDUSTRY

The inorganic arsenic standard under the National Emission Standards for Hazardous Atmospheric Pollutants (NESHAPs), possible changes in the sulfur oxides standard due to the current EPA review as authorized by the CAA (75), and regulatory changes resulting from proposed acid rain legislation may add increased control requirements and costs to the lead industry.

Primary and secondary lead smelters have been identified by EPA as a source of inorganic arsenic emissions. Arsenic has been listed as a hazardous substance in 1980 and targeted for control. In the proposed standards issued in July of 1983, EPA indicated that, at that time, it did not intend to control lead smelter arsenic emissions because of their current low levels.

Since significant SO_2 emissions are generated, primary lead producers may be subject to new regulations designed to attain possible changes in the NAAQS for SO_2. This emission issue could potentially impact primary lead smelters since sintering of lead sulfide ores is a high source of SO_2 at the five primary smelting facilities in the U.S. Lead smelters meet present SO_2 NAAQS with existing technologies and control strategies (68). Strategies include the use of supplemental control systems (tall stacks and production curtailment) and intermittent control systems (capture of SO_2 gas steams). The 1977 amendments to the CAA prohibit the use of these control strategies to achieve NAAQS after 1987.

Acid rain legislation is of concern to primary producers in Missouri, the site of over 90 percent of primary U.S. lead production. Proposed legislation calls for stringent SO_2 controls in the 31 States east of and immediately bordering on the west side of the Mississippi River. A Presidentially-appointed scientific panel recommended acid rain legislation to reduce SO_2 emissions as soon as possible. Nonferrous smelters would be regulated along with utilities (76).

D. GENERAL CONCLUSIONS

1. In the case of modifications to existing facilities, monitoring rather the modeling may be more appropriate to establish baseline emissions.

2. Greater emphasis on site-specific conditions should receive more consideration in determining specific regulatory requirements.

3. Additional research and demonstration projects on potential control technologies prior to establishment of regulatory technical standards would probably increase regulatory effectiveness and decrease the economic impact.

CHAPTER 5.—THE RESOURCE CONSERVATION AND RECOVERY ACT OF 1976, AND THE SUPERFUND ACT OF 1980

A. THE RESOURCE CONSERVATION AND RECOVERY ACT OF 1976 AND REGULATIONS PURSUANT TO THE LEAD INDUSTRY

The Resource Conservation and Recovery Act of 1976 (RCRA) amended the Solid Waste Disposal Act. The objectives of RCRA are "to provide technical and financial assistance for the development of management plans and facilities for the recovery of energy and other resources from discarded materials and for the safe disposal of discarded materials, and to regulate the management of hazardous waste" (80). A major objective of the statute is the protection of groundwater.

Classifying Wastes as Hazardous

Solid and hazardous wastes are defined as follows (78):

> "The term 'solid waste' means any garbage, refuse, sludge... and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining and agricultural operations..." (3).
>
> The term 'hazardous waste' means a solid waste, or combination of solid wastes, that because of quantity, concentration, or physical, chemical, or infectious characteristics may:
>
>> (A) "cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or
>>
>> (B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise mismanaged" (3).

Two mechanisms are available for classifying a waste as hazardous. Under subpart C of 40 CFR Part 261, a solid waste exhibiting any of the characteristics of ignitability, corrosivity, reactivity, or toxicity under a designated test is deemed hazardous; and any waste listed in subpart D of 40 CFR Part 261 is hazardous. Under these criteria, spent batteries may also be classified as hazardous because of either sulfuric acid (corrosivity and toxicity) or lead (toxicity). Other lead-bearing materials could also be classified as hazardous under the extraction procedure (EP) test for toxicity. Under the subpart D listing of hazardous wastes, secondary lead smelting emission control dusts and sludges and waste leaching solutions from acid leaching of these dusts and sludges are listed as hazardous wastes (78). However, such materials were exempted from hazardous waste regulation under RCRA when Congress amended the original Solid Waste Disposal Act in 1980.

Some secondary lead operators doubt that the dusts and sludges from secondary emission controls should categorically be characterized as hazardous. Quarles points out that EPA regulations "treat any petition for delisting as seeking an amendment of existing regulations and therefore subject to the time-consuming procedures of rulemaking" (78). Thus, to delist a material, EPA would be required to publish a notice of proposed rulemaking and allow representatives of industry and the public to comment.

Manifest System

A salient feature of RCRA is the manifest system for hazardous wastes. A manifest is prepared by the generator of hazardous waste and is used to monitor the transportation and disposal of the hazardous material. Generators of hazardous waste must obtain an EPA identification number for the manifest form. Additionally on the manifest are EPA identification numbers of the transporters and the treatment, storage, and disposal facility (TSDF) designated to handle the waste. Neither transporters nor TSDF's may accept hazardous waste without an accompanying manifest. "In short, the manifest system is intended to place a clear responsibility on each generator to determine the ultimate disposition of its wastes and to provide assurance that the wastes go where they are sent" (78). Copies of the manifest go to each handler of the waste, and a copy goes to the generator to confirm that the waste is delivered. If after 35 days the generator receives no return copy, he must inquire to verify delivery of the waste. If within 45 days he is unable to verify delivery, an Exception Report must be filed with the EPA Regional Administrator (78).

Transporter regulations under RCRA incorporate Department of Transportation regulations previously in effect under the Hazardous Materials Transportation Act. Other requirements of transporters under RCRA include the acquisition of an EPA identification number and use of the manifest system in handling any waste. If transporters mix hazardous wastes having different manifest descriptions, they are considered generators of hazardous wastes and must comply with RCRA generator standards under 40 CFR Part 262 (78).

Operators of TSDF's must return a manifest copy to the generator upon receiving a shipment of hazardous waste. A copy of the manifest at the TDF must be maintained for three years. If significant discrepanices are found in the delivered material compared to that described on the manifest and the discrepancy cannot be reconciled with the transporter or generator, the TSDF operator must report the discrepancy to the EPA Regional Administrator within 15 days. Similarly, the operator must report waste received from off-site that is hazardous and not manifested (78).

Regulation of Recycling Activities

The statutory definition of "hazardous waste" includes materials characterized as hazardous "when improperly treated, stored, transported or disposed of, or otherwise mismanaged" (79). Because of the potential for mismanagement, EPA regulates operations that both store and reclaim spent batteries. According to EPA, "a recycled material's regulatory status would depend upon both what the material is and how it actually is managed—and the status could vary with the means of recycling" (79). In the case of the secondary smelters and battery breakers, EPA has documented contamination of groundwater by sulfuric acid and leached metals through mismanagement of spent batteries (79). EPA proposed to regulate spent lead-acid batteries "only when stored before reclamation at battery cracking, battery cracking-smelting operations, or battery cracking-smelting-refining operations" (79). However, EPA proposes to "exclude spent batteries from regulations when they are accumulated by persons other than reclaimers, or when they are transported" (79). Exclusion obviates compliance with EPA's manifest requirements for generators and transporters of spent batteries.

Exclusion is based on three considerations (79):

(1) Spent batteries are the main source of secondary material to the industry.

(2) Acid spillage during transport of spent batteries is unlikely. Furthermore, Department of Transportation requirements for the transportation of hazardous materials would control movement of batteries under 49 CFR Part 122.

(3) Secondary operators pay for batteries on a weight basis; consequently, transporters may have an incentive to deliver batteries filled with acid.

Secondary smelter operators and battery manufacturers (both integrated and nonintegrated) must follow EPA manifest and hazardous waste disposal regulations for off-site shipments of: (1) wastes from battery breaking operations; (2) cuttings, dust and other wastes from new battery manufacturing operations; (3) listed secondary lead smelting emission control dusts and sludges; (4) waste leaching solutions from listed dusts and sludges; and (5) slag and other process wastes that fail the EP toxicity test.

An additional factor is the development of State programs to administer enforcement provisions of RCRA. Section 3009 of the Act prohibits States from imposing any standards that are less strict than Federal standards. However, States are allowed to be more stringent than the Federal Government in imposing standards (Solid Waste Disposal Act Amendments of 1980, 94 STAT. 2342 at 42 USC 6929). State programs were to be authorized by EPA before January 26, 1985. For States in which there is not a federally approved State program by that date, enforcement authority reverts to the Federal Government (78).

B. TEMPORARY EXEMPTION FOR PRIMARY PRODUCERS UNDER RCRA

On October 21, 1980, Congress directed EPA not to regulate primary producers under the hazardous waste provisions of RCRA. This exemption came about through the Solid Waste Disposal Act Amendments of 1980. The 1980 amendments specifically exempted "solid waste from the extraction, beneficiation, and processing of ores and minerals" from regulation under Section 3001 concerning hazardous wastes (4). Exemption was granted because more data and analyses were needed concerning the hazardous nature of materials derived from the beneficiation and processing of ores to require their regulation under the hazardous waste provisions. Accordingly, Section 8002 to the Act was amended to require the EPA Administrator to conduct a three-year study of these materials to determine, among other things, the "potential danger, if any, to human health and the environment from the disposal and reuse of such materials" and to "document cases in which danger to human health or the environment has been proved" (81). The study was to be completed by October 21, 1983. Section 3001 of the Act was amended to require the Administrator to decide, within six months after completion of the study, whether or not to promulgate regulations controlling the handling of these materials.

C. THE EXTRACTION PROCEDURE TEST FOR TOXICITY OF LEAD-BEARING WASTES

The extraction procedure (EP) test is prescribed by EPA to determine the toxicity of lead-bearing wastes under 40 CFR, Section 261.2 (1981). The EP test involves subjecting waste material to 0.5 N acetic acid at pH 5 for 24 hours, if the resultant extract yields a maximum concentration of 0.5 milligrams of lead per liter, the material is considered a hazardous waste (78). However, acetic acid is one of the few commonly occurring acids that will dissolve most lead forms. Acetic acid is not as likely to be encountered at industrial disposal sites as other leachates, such as tannic and dilute sulfuric acid or water. A justification factor for the use of the acetic acid EP test was the potential for mishandling lead-bearing industrial wastes in such a way that they could be placed in municipal landfills. Under such conditions organic acids, such as acetic acid, could be generated that would leach lead into the environment.

D. STATE ENFORCEMENT PROGRAMS AND STATE AUTHORITY

Section 3009 of RCRA, as amended by the Solid Waste Disposal Act Amendments of 1980, states that "Nothing in this title shall be construed to prohibit any State or political subdivision thereof from imposing any requirements, including those for site selection, which are more stringent than those imposed by such regulations" (79). Section 3006 of RCRA allows the Administrator to refuse authorization to any State RCRA program if it is (1) "not equivalent to the Federal program;" (2) "not consistent with the Federal or State programs applicable in other States;" or (3) does not "provide adequate enforcement or compliance" (80).

Quarles states that: "The consistency requirements evidently will not be applied by EPA to curtail stricter state standards... except with respect to interstate transportation and waste importation ban issues" (78). States may (1) impose additional notification and registration requirements on more facilities, (2) require less than 90 days for temporary on-site storage of waste, or (3) define hazardous wastes to cover a broader range of materials. According to Quarles, "The biggest immediate problem is confusion, which affects many aspects of program operations during the transitional phase while State programs are being established" (77).

State regulation pursuant to RCRA could present compliance problems in the following areas: (1) possible State reluctance to permit new industrial waste disposal facilities; (2) shipment of materials from States in which the materials are deemed hazardous to States in which the materials are deemed not hazardous, and vice versa; (3) competition between facilities operating in differing States, one of which treats a secondary feed material as hazardous and the other which does not; (4) multiplant firms attempting to maintain the various requirements for the States in which their plants operate.

E. RCRA REQUIREMENT RAMIFICATIONS REGARDING THE COMPREHENSIVE ENVIRONMENTAL RESPONSE, CONSERVATION, AND LIABILITY ACT OF 1980 (CERCLA or SUPERFUND)

Lead smelter and battery plants may be subject to hazardous waste protection programs and post-closure care programs after operations cease. CERCLA provides the Federal Government with the authority to remove hazardous substances from active and inactive disposal sites and to assist the States in emergency situations. As in RCRA, the primary objective of CERCLA is to protect groundwater through removal of contaminants (78). Federal cleanup efforts are to be funded through the "Hazardous Substance Response Trust Fund," financed by taxes on crude oil, petroleum products, and chemical feedstocks, and from general Federal revenues. Lead oxide is among the chemical feedstocks (78).

Under CERCLA, financial responsibility for cleanup can be placed on the companies that caused the disposal problem. For identified sites, the EPA may request companies deemed liable to perform the cleanup at company cost. Upon refusal, EPA may implement a cost-effective remedial program using money from the Trust Fund. EPA can sue the companies for reimbursement. EPA is prohibited from cleanup action if the responsible company or companies voluntarily undertake the required cleanup. In cases where a number of companies are included, financial liability is allocated according to the nature of the contamination and quantities of waste contributed by the respective firms. Liability for cleanup costs under CERCLA is established for owners and operators of disposal facilities, generators, and transporters of hazardous wastes (1).

Under CERCLA, EPA may issue "administrative orders" directing an operator to take specific remedial measures. CERCLA authorizes punitive treble damages to be imposed for failure to comply "without sufficient cause" (1).

Another requirement of CERCLA with ramifications for lead and battery producers is the "Post-Closure Liability Trust Fund" financed by a per-ton tax on the receipt of hazardous waste at TSDF's, and levied beginning September 30, 1983 (CERCLA, Section 231, 42 USC Section 9641). Liability under CERCLA and RCRA can be transferred from operators to the Post-Closure Liability Trust Fund after the following conditions have been met: (1) the facility has been issued and complied with a permit pursuant to RCRA, subtitle C;(2) the facility has been closed in compliance with RCRA regulations and permit conditions; and (3) the area in the vicinity of the facility has been monitored for five years to establish that there is no substantial risk to public health and that hazardous materials will be contained (1).

EPA's methodology for determining remedial action "emphasizes cost-effective, environmentally sound remedies which are feasible and reliable from an engineering standpoint" (80).

By December 1982, EPA targeted 418 sites for priority action under CERCLA. Of the 17 mine, mill, and smelter sites included in the list, six were lead or battery producers: Bunker Hill Company, Smelterville, Idaho; Harbor Island Lead, Seattle, Washington; Sapp Battery, Cottondale, Texas; Schuylkill Metals, Plant City, Florida; National Lead-Taracorp, St. Louis Park, Minnesota; and Marathon Battery, Cold Springs, New York. Another Superfund site is the inactive Tar Creek lead and zinc mining district near Picher, Oklahoma. The applicability of CERCLA to this site is legally unresolved because it is a mining area and not technically a waste disposal site. Tar Creek, however, provides an example of the broad authority given to the Federal Government under CERCLA.

The ramifications of CERCLA for lead and battery producers have yet to be fully assessed. However, several industry represenatives have indicated concern that closed lead smelters may become Superfund sites.

F. GENERAL CONCLUSIONS

1. Recycling of lead appears desirable for both environmental and conservation reasons. Therefore, regulations should encourage recycling of lead without placing undue regulatory burdens on responsible secondary producers.

2. Lead industry recycling and waste disposal practices should be reviewed in regard to the EP toxicity test using acetic leachates. An alternative EP test using carbonic, tannic, or dilute sulfuric acid or water may be more appropriate.

3. There are concerns that closed lead smelters eventually may be perceived as Superfund sites. To the extent that those concerns come to pass, CERCLA may serve as a deterrent to the closure of uneconomic facilities. For multiplant firms, the threat of Superfund cleanup actions for closed facilities may appear more costly to the parent company than using its profitable operations to subsidize its unprofitable ones.

CHAPTER 6. - THE ENVIRONMENTAL PROTECTION AGENCY'S (EPA) EFFLUENT STANDARDS UNDER THE CLEAN WATER ACT

Water regulations affect all three lead industry sectors. Three Congressional Acts form the basis of the Federal water regulations: 1) the Federal Water Pollution Control Act (Clean Water Act) of 1972, 2) the Safe Drinking Water Act (SDWA) of 1977, and 3) the Clean Water Act (CWA) of 1977. A significant impact of the SDWA is the requirement for ground water monitoring by wells at the facilities to detect the possible pollution of aquifers.

The Federal Water Pollution Control Act (FWPCA) of 1972 (33 U.S.C. 1251 as modified by P.L. 92-500) focused on "conventional pollutants," such as, but not restricted to, pH and total suspended solids (TSS). Point source primary and secondary lead discharges (underground mines, mills, smelters and refineries) were required to meet effluent standards by July 1, 1977, as set by EPA. Initially, standards were to be met by installation of the Best Practicable Control Technology (BPT) followed by the Best Available Technology (BAT) on July 1, 1984, (table 6-1 and 6-2, 33 U.S.C. 1251). New Source Performance Standards (NSPS) were promulgated based on the Best Available Demonstrated Technology (BADT) or BAT to be installed prior to facility operation. BAT was to be utilized by existing primary and secondary facilities and battery plant sources by July 1, 1984 (tables 6-1 and 6-2). Regulations on direct discharges were incorporated into the existing National Pollutant Discharge Elimination System (NPDES) permitting process. Existing and new indirect dischargers were required to meet Pretreatment Standards as Existing Sources and Pretreatment Standards New Sources (PSES and PSNS, respectively) prior to discharge to a publicly-owned wastewater treatment works (POTW, tables 6-1 and 6-2). Final rules on discharges by smelters and refineries to POTW were published (82).

The National Resources Defense Council, Inc. (NRDC) and other environmental groups filed suit against EPA in 1976 concerning regulations covering toxic liquid waste discharges. A settlement was subsequently reached in which EPA agreed to promulgate BAT effluent guidelines, pretreatment standards, and NSPS covering 21 major industries and 65 priority toxic pollutants. The agreement was written into the Clean Water Act of 1977, that shifted the emphasis to toxic or hazardous pollutants. EPA was to establish BAT for unconventional and nontoxic pollutants by July 1, 1984, with compliance due within 3 years of promulgation, but no later than July 1, 1987.

The Clean Water Act of 1977 (P.L. 95-217) required that effluent guidelines be met through BAT for toxic pollutants, whereas control of "conventional" pollutants was to be by the "Best Conventional Control Technology" (BCT). BCT limits, based on a two-part "cost-reasonableness" test, were the result of a 1981 suit by the American Paper Institute against EPA. A cost-reasonableness test

Table 6-1 - Federal Water Regulations Impacting the Primary Lead Industry

TABLE 6-1.- Federal water regulations impacting the primary lead industry

Production Phase	EPA Category	Status	Effective Date	Standard Control Technology
		Best Practicable Control Technology (BPT)		
Mining	Ore Mining and Dressing	Promulgated as interim final rules 11-6-75 withdrawn 5-11-78	7-1-77	None specified, normally pH adjustment with lime and sedimentation in a primary pond.
Do.	do.	Promulgated as final rules 7-11-78	7-11-78	do.
Milling	do.	Promulgated as interim final rules 11-6-75 withdrawn 5-11-78	7-1-77	do.
Do.	do.	Promulgated as final rules 7-11-78	7-11-78	do.
Do.	do.	Amendment eliminating cyanide limitations, promulgated 3-1-79	3-1-79	do.
Smelting and smelter based refineries and acid plants	Nonferrous Metals Manufacturing—Primary Lead Subcategory	Promulgated as interim final rules 2-27-75	7-1-77	No discharge complete process water recycle following neutralization, setting, and disposal in impoundments with discharge allowances for catastrophic stormwater and net monthly precipitation (less solar evaporation).
Smelting and all refining	do.	Proposed 2-17-83	—	Lime precipitation and sedimentation with discharge allowance as a blast furnace slag granulation bleed stream.
Do.	do.	Promulgated as final rules 3-22-84, published 3-8-84	4-23-84	Lime precipitation and sedimentation on allowable processes discharges, no stormwater and net precipitation allowances.
Sulfuric acid plants	Nonferrous Metals Manufacturing—Metallurgical Acid Plants Subcategory	Promulgated as final rules 3-22-84, proposed 2-17-84, published 3-8-84	4-23-84	Lime precipitation and sedimentation, no discharge allowances for stormwater and net precipitation.
		Best Available Control Technology (BAT)		
Mining and milling	Ore Mining and Dressing	Promulgated as final rules 12-17-82 proposed 6-14-82, published 23-3-82	1-17-83	None specified, normally pH adjustments with lime and sedimentation in primary ponds.
Smelting and smelter based refineries and acid plants	Nonferrous Metals Manufacturing—Primary Lead Subcategory	Promulgated as interim final rules 2-27-75	7-1-83	No discharge (100 pct. recycle), control by impoundments with net monthly precipitation and catastrophic stormwater discharge allowances.
Smelting and all refineries	do.	Proposed 2-17-83	—	In process flow reduction and recycle, lime precipitation and sedimentation plus polishing filtration on blast furnace slag granulation bleed stream.
Do.	do.	Promulgated as final rules 3-24-84 published 3-8-84	7-1-84	In process flow reduction and recycle, lime precipitation and sedimentation, followed by sulfide precipitation, sedimentation, and multimedia filtration, sulfide precipitation not required if only hygene wastewaters treated.
Sulfuric acid plants	Nonferrous Metals Manufacturing—Metallurgical Acid Plants Subcategory	Proposed 2-17-83	—	Lime precipitation and sedimentation followed by polishing filtration and flow reduction (scrubber water recycle).
Do.	do.	Promulgated as final rules 3-22-84, published 3-8-84	7-1-84	In process flow reduction and recycle, lime precipitation and sedimentation, followed by sulfide precipitation and sedimentation and multimedia filtration

TABLE 6-1. - Federal water regulations impacting the primary lead industry (continued)

Production Phase	EPA Category	Status	Effective Date	Standard Control Technology
Best Conventional Pollutant Control Technology (BCT)				
Mining and milling	Ore Mining and Dressing	Proposed 6-14-84 and not promulgated pending approval of BCT methodology	—	None specified, normally pH adjustment with lime and sedimentation in primary ponds.
Smelting and refining and sulfuric acid plants	Nonferrous Metals Manufacturing—Primary Lead Subcategury and Metallurgical Acid Plant Subcategory	Proposed 2-17-83 and not promulgated pending approval of BCT methodology	—	Lime precipitation and sedimentatio plus in-process flow reduction and recycle.
New Source Performance Standards (NSPS) — Best Available Demonstrated Technology (BDT)				
Mining	Ore Mining and Dressing	Promulgated 12-17-82, proposed 6-14-82, published 12-3-82	After 1-17-84, the date the operation begins	None specified, normally pH adjustment with lime and sedimentation in primary ponds.
Milling (froth floatation process)	do.	do.	do.	No discharge (100 pct. recycle), discharge allowances for net annual precipitation and as a mill water bleed stream to correct for contaminant buildup that impedes product delivery that cannot otherwise be corrected.
Smelting and all refining	Nonferrous Metals Manufacturing—Primary Lead Subcategory	Promulgated 3-22-84, published 3-8-84 proposed 2-17-83	After 4-23-84, the date the operation begins	No discharge except for certain hygene wastewaters after treatment by lime precipitation sedimentation, and multimedia filtration to meet BAT and BCT limitations.
Sulfuric acid plants	Nonferrous Metals Manufacturing—Metallurgical Acid Plants Subcategory	do.	do.	In process, flow reduction (90 pct. recycle) lime precipitation and sedimentation, followed by sulfide precipitation, sedimentation, and multimedia filtration.
Pretreatment Standards Existing Sources (PSES)				
Smelting and all refining	Nonferrous Metals Manufacturing—Primary Lead Subcategory	Promulgated 3-22-84, published 3-8-84	3-9-87	Lime precipitation and sedimentation, followed by sulfide precipitation, sedimentation, and multimedia filtration (equivalent to BAT)
Sulfuric acid plants	Nonferrous Metals Manufacturing—Metallurgical Acid Plants Subcategory	do.	3-9-87	In process, flow reduction and 90 pct. recycle followed by lime precipitation, sedimentation, sulfide precipitation, sedimentation, and multimedia filtration (equivalent to BAT).
Pretreatment Standards New Sources (PSNS)				
Smelting and all refining	Nonferrous Metals Manufacturing—Primary Lead Subcategory	Promulgated 3-22-84, published 3-8-84	After 4-23-84, the date the operation begins	No discharge except for hygene wastewaters after treatment to meet BAT and BCT limitations by lime and settle followed by multimedia filtration (equivalent to NSPS).
Sulfuric acid plants	Nonferrous Metals Manufacturing—Metallurgical Acid Plants Subcategory	do.	do.	Recycle 90 pct. of wastewater, treatment of effluent by lime and settle followed by sulfide precipitation, sedimentation, and multimedia filtration (equivalent to NSPS and BAT).

TABLE 6-2. - Federal water regulations impacting the secondary lead smelting and battery manufacturing industries

Regulation	Sector	Effective Date	Standard Control Technology [1/]
BPT	Secondary smelting	4-23-84	Lime precipitation and sedimentation
	Battery Plants	4-18-24	Oil skimming, lime precipitation and sedimentation
BAT	Secondary smelting	7-1-84	Lime precipitation and sedimentation, plus multimedia filtration, flow reduction
	Battery plants	7-1-84	Oil skimming, lime precipitation and sedimentation flow reduction reduction
NSPS	Secondary smelting	After 4-23-83 the date operations begin	Lime precipitation and sedimentation, plus multimedia filtration and additional flow reduction
	Battery plants	After 4-18-83 the date operations begin	Oil skimming, lime precipitation and sedimentation, plus multimedia filtration and additional flow reduction
PSES	Secondary smelting	3-9-87	Equivalent to BAT
	Battery plants	3-9-87	do.
PSES	Secondary smelting	After 4-23-83 the date operations begin	Equivalent to NSPS
	Battery plants	After 4-18-83 the date operations begin	

[1/] Not specifically required under EPA regulations, but comprise the technologic basis used by the agency in the effluent limitation formulations. By implementing these technologies the guideline limits should be met.

must compare the private industry water pollution control cost against the POTW/pretreatment cost for conventional pollutant control and the cost of additional control beyond the BPT level. If EPA decides that under both test parts, the BCT guidelines are reasonable for the facility, the BCT is established. Best Conventional Control Technology must be at least as stringent as BPT for the regulated pollutants. A revision to the proposed BCT rules was published on October 29, 1982, that included lead mines and mills under the "Ore Mining and Dressing" category (table 6-1). Proposed BCT limitations, guidelines, and standards were published for primary lead smelters, refineries, and acid plants and secondary lead smelters/refineries on February 17, 1983, (84). The final rulemakings for BCT have been delayed pending judicial approval of BCT methodology.

Additionally, dischargers may be subject to process controls as a preventive measure to avoid toxic or hazardous effluent discharges through rain runoff, spillage, process leakage, and solid waste disposal. Known as "best management practices" (BMP), these additional controls are the responsibility of potential toxic dischargers. Although no BMP standards have been promulgated, such practices may be required by the permitting agency during NPDES permitting procedures.

New Source Performance Standards (NSPS) and new and existing source pretreatment standards (PSNS and PSES, respectively) were modified by the CAA of 1977 to emphasize toxic pollutants. Proposed rules for new source and pretreatment standards were published on February 17, 1983, (84) for primary and secondary facilities and on November 10, 1982, for battery plants (85).

The primary lead industry is one of 21 major industries regulated by the Clean Water Acts of 1972 and 1977. In addition, sulfuric acid plants, used for air pollution control at most lead smelters, are also regulated under the category "metallurgical acid plants." In 1980, this category included only copper smelter acid plants. Proposed rules of February 17, 1983, and final rules of March 22, 1984, placed lead and zinc smelter-based acid plants in this category. Previously, lead and zinc smelter acid plants were regulated under smelter standards.

A. MINING AND MILLING REGULATIONS

Lead mining and milling water discharges are regulated under the "Ore Mining and Dressing" category. On November 6, 1975, BPT was promulgated in interim final form. On May 11, 1978, EPA withdrew primary lead mine and mill BPT standards for reconsideration and promulgated revised final rules on July 11, 1978 (table 6-1). Revised effluent limitations set slightly higher levels of copper, lead, zinc, and cyanide (mills only) that are allowable in point source discharges (87). Data subsequently submitted to EPA by industry demonstrated that cyanide was not present in froth flotation mill wastewater. EPA removed the cyanide effluent limitation on March 1, 1979 (88). The BPT regulations were upheld in a court decision on December 10, 1979. For mines and mills, BAT was proposed originally on November 6, 1975, but subsequently withdrawn on March 19, 1981, along with NSPS, PSES, and

PSNS proposals. Standards were reproposed on June 14, 1982, and promulgated December 17, 1982 (table 6-1; 89). NSPS is equivalent to BAT in the proposal except for froth flotation mills. New lead mills will be required to recycle 100 percent of the water (zero discharge) because froth flotation is the current standard beneficiation technology. Effluent limitations are concentration-based in the Ore Mining and Dressing category instead of a mass-based standard as used in the Nonferrous Metals Manufacturing category. Active mines and mills are considered point sources. However, abandoned or inactive metal mine lands are considered nonpoint water pollution sources by EPA.

BMP's were expected to be proposed in the near future to control nonpoint pollution sources (91). No PSNS or PSES standards were promulgated or proposed for the Ore Mining and Dressing Category.

On June 4, 1982, EPA revised the effluent limitations for pH for discharges from point sources requiring sources that continuously monitor pH to achieve compliance 99 percent of the time. Previously facilities were required to maintain compliance 100 percent of the time. The relief, allowing for unforeseen equipment failures and maintenance, was the result of an industry petition. Most domestic lead and zinc-lead mines do not have acidic drainage. However, certain northeastern and northwestern U.S. mines have acidic drainage and, therefore, could be affected by the pH rule.

B. PRIMARY LEAD SMELTING AND REFINING REGULATIONS

Under the interim final regulations, primary lead refineries separate from smelters are excluded from BPT and BAT, whereas water effluent from refineries located at smelters are regulated under the lead smelter standard (table 6-1). Recently, proposed revisions (84) and the promulgated standard (82) included separate lead refineries which would be regulated under the primary lead category.

As of April 23, 1984, lead smelters, refineries, and associated sulfuric acid plants were regulated under the revised final rules, promulgated March 22, 1984. Previously, no discharges were allowed from these facilities except for discharge allowances for catastrophic storms, and net monthly precipitation to remove excessive amounts of water that comingled with the contaminated process water stored in surface impoundments. This discharge was to be treated and must meet the limitations for areas with net evaporation (El Paso and East Helena) and net precipitation (the Missouri smelter/refineries). Under new regulations, there are no such discharge allowances, but plants could obtain variances through the NPDES permit process if such a requirement can be demonstrated. Discharge allowances are mass-based and allowable for certain process wastewaters and the small volume of wastewater required for industrial hygiene control. Additional effluent treatment technology is required for BAT for increased contaminant collection (sulfide precipitation and multimedia filtration), to begin July 1, 1984.

No primary lead smelter, refineries or acid plants discharge to POTW. Therefore, EPA has not proposed pretreatment standards (PSES) for these facilities. However, new primary lead smelters/refineries may wish to utilize a POTW. EPA has proposed NSPS and PSNS that would require complete process water recycle (zero discharge) without allowances for bleed streams, catastrophic storms or floods, and net precipitation. EPA added allowances for industrial hygiene-related wastewaters.

Therefore, in the final standard of March 22, 1984, EPA promulgated PSES standards in which the existing nonferrous metals plant must pretreat effluents to meet the limitations of BAT, NSPS and PSNS. Under NSPS, process water must be recycled. EPA indicates that to accomplish this: 1) air pollution control is to be by dry methods 2) slag granulation water is to be recycled, and 3) sulfuric acid plant effluent (blowdown) is to be recycled. Only certain hygiene wastewaters are allowed to be discharged after treatment.

C. SECONDARY LEAD SMELTING AND REFINING REGULATIONS

Regulation of secondary lead facilities was addressed by Phase I of the Nonferrous Metals Manufacturing category promulgation. Regulations were proposed February 17, 1983, and promulgated March 8, 1984, and included BPT, BAT, PSES, NSPS, and PSNS standards. Because of the EPA reconsideration of BCT rules in response to legal action, no BCT regulations have been proposed for this subcategory. Conventional pollutants from secondary smelter/refineries were controlled by BPT regulations. Toxic pollutants regulated included antimony, arsenic, lead, zinc, and ammonia. Ammonia was added because the pollutant was present in wastewaters from a treatment plant that utilized ammonia in place of lime or other hydroxides in wastewater treatment. EPA suggested that soda ash or caustic could be substituted for ammonia in an the effort to produce a more recyclable treatment plant sludge. Control technology required lime neutralization and settlement. This technology would also limit cadmium, chromium (total), copper, and nickel that may be present in the wastewater. To increase toxic metal removal efficiency, BAT technology also requires the addition of multimedia filtration after settlement. Discharge allowances are included: (1) for waste streams arising from compliance measures to OSHA occupational hygiene regulations, (2) for the washing of spent battery delivery trucks, (3) for EPA lead in air emission controls, and (4) chemical laboratory wastewaters.

D. BATTERY PLANT REGULATIONS

Lead-acid battery plants are regulated under separate EPA point source category standards promulgated March 9, 1984 (82). The final rule incorporates: (1) the standards proposed November 10, 1982, (85) for the "Battery Manufacturing" category; (2) regulations concerning lead molding and casting wastewaters, previously proposed under the "Metal Molding and Casting Industry" category (92) (82), and (3) additional processes and industrial hygiene measure wastewaters developed in preparation of the final rule (82). Integrated facilities that are direct dischargers to "navigable" waters are subject to individually permitted (NSPDES process) standards developed by the permitting authority using "Best Professional Judgement" (BPJ). With BPJ, the authority (State, local agency or EPA region) should allow credits for each promulgated allowance in combined flows. Cotreatment of wastewater should meet mass limitations developed for combined flow, promulgated February 17, 1983. Integrated facilities that are indirect dischargers are subject to combined flow limitations of the "Combined Waste Stream Formula" developed for industrial discharges to a POTW (93). Discharges are not permitted for closed operations in BAT, NSPS, PSES, and PSNS, nor for pallet washing, lead oxide production, casting curing, and lead rolling operations, nor for lead melting furnace and die casting wet scrubbers. Non-regulated flows include shower wastewater, cooling tower blow down, and water softener and deionizer back flush.

BMP's were not developed for battery plants. Additional discharge allowances may be permitted at an individual facility for such wastewaters as: 1) leachate from an on-site inactive landfill, 2) stormwater runoff, 3) effluent from the dewatering of off-site produced sludges, and 4) lead rolling. Allowances may be permitted for upset and bypass provisions developed under NPDES procedures (93). Regulated pollutants for the Lead Battery Manufacturing subcategory are lead, copper and iron, pH, Total Suspended Solids (TSS), and oil and grease. However, other metals such as, antimony, cadmium, chromium, mercury, nickel, silver, and zinc are controlled to varying degrees by the required technologies.

E. VARIANCE PROCEDURES

Permits for industrial facilities are issued for BPT, BAT, BCT, and NSPS through NPDES. Variances were not available for NSPS, but BPT, BAT, and BCT are subject to the "fundamentally different factors" variance if the discharger demonstrates that the facility is significantly different from those used in the formulation of standards. Variances can be obtained for new facilities discharging to a POTW for either "fundamentally different factors" or if sufficient removal of the polluants can be demonstrated. Compliance extensions for the BAT deadline of July 1, 1984, to a date no later than July 1, 1987, may be obtained for facilities that meet BPT requirements and install innovative technologies for wastewater treatment. Two options are available: 1) installation of innovative technology producing a significant reduction in pollutant discharges above BAT technologies, or 2) installation of an innovative technology, equivalent to BAT but at a significantly lower cost. Both options require that the technologies have the potential for industry-wide application. Microfiltration technology (reverse osmosis) for segregated battery plant waste streams would be an example of such a technology.

Chapter 7 - INNOVATIVE TECHNOLOGIES TO MITIGATE ENVIRONMENTAL EFFECTS OF LEAD PRODUCTION

A. DEVELOPING PRIMARY SMELTING TECHNOLOGY

Most new lead smelting technologies are based on direct, concentrate-to-bullion processes. Such technologies avoid the inherent thermal inefficiency of the two-step sintering plant and blast furnace smelting process and the associated environmental control and manpower costs. Direct smelting processes have intensified reaction rates by using technically pure oxygen or oxygen-enriched combustion gas. Processes can be categorized into four types: (1) flash furnaces, (2) pneumatic reactors, (3) units that combine features of both and (4) units that are either fuel fired or electrothermic (95,96). Intensification of reactions allows for a much higher smelter throughput and lower waste gas volume, lowering capital costs and simplifying pollution control requirements. Several newer processes are also reported capable of smelting and separating major constituents of complex feed materials either for metal production or to process primary smelter intermediate and waste products (97, 98). Another process, the Top Blown Rotary Converter (TBRC), is also capable of smelting inhomogeneous feed materials (99). A similar process, the Isamelt process, is being developed to treat lead concentrates in Australia (100). Two pyrometallurgical technologies have demonstrated promise for widespread application in the near future, the Queneau-Schuhmann-Lurgi (QSL) and Kivcet (CS variant) processes.

QSL incorporates autogenous smelting and direct reduction in a single furnace. Pelletized lead concentrates are charged continuously to the melt, and submerged injectors continuously supply oxygen to completely oxidize sulfides. This process reduces fossil-fuel costs by more than one-third. Concentrated sulfur dioxide (SO_2) exhaust gas produced (more than 15 percent SO_2) facilitates removal of the pollutant in sulfuric acid plants. Two German companies participated with the government of the Federal Republic of Germany (FRG) to build a 30,000 ton-per-year demonstration plant in Duisburg, FRG, using the QSL process. Because the lead concentrate is pelletized, low fugitive emissions are produced. Low smelting temperatures minimize lead fuming, resulting in a reduction of from 20 to 25 percent in flue dust emissions. In 1983 the cost of a QSL plant, excluding the oxygen and sulfuric acid plants and refinery and casting facilities, was $32 million. Energy required to generate pure oxygen process gas is obtained from heat recovered from the offgases (101). For retrofit installations, lead refinery and support facilities would already be in place. However, considering the size of domestic facilities, two to three QSL reactor vessels would be required to maintain production during major maintenance.

The Kivcet-CS direct-reduction furnace, developed in the Soviet Union, is a flash process that eliminates the sinter plant, blast furnace and slag fuming operations by using one autogenous smelting unit. A Kivcet unit has three components: (1) a vertical flash smelting shaft, (2) an electric reduction furnace, and (3) a water-cooled wall. The wall permits the melt to pass into the reduction furnace while isolating the SO_2-bearing gas in the shaft. In 1983, a Kivcet plant of 22,000-ton lead capacity was under construction in Karachipampa, Bolivia with scheduled operation expected in late 1984.

Bolivian and foreign ores are to be used to produce, in addition to lead, 3,000 tons of zinc, 1,000 tons of antimony, 600 tons of copper, 800 tons of tin, and 200 tons of silver per year. Cominco, Ltd. of Canada has announced that two Kivcet furnaces will be built, beginning in late 1984, to replace the sinter-blast furnace process at its Trail, B.C. smelter. The $140 million (Canadian) project will extend the capacity to 160,000 tons-per-year. Improvements to the lead refinery are also anticipated by installation of the Cominco-Bipolar electrolytic refining process to replace the Betts electrolytic plant in operation since the early 1900's (102). As with the QSL process, the Kivcet-CS process is designed to achieve optimum metal recoveries with less environmental contamination, and lower labor and capital costs than conventional smelting (103, 104).

The top blown rotary converter (TBRC) has the potential for application because of flexibility inherent in converter operations. The TBRC is a batch furnace with attendant hygiene hazards associated with charging and tapping operations; however, complete encapsulation of the furnace in a ventilated enclosure should reduce the hazards. A Demag of West Germany (FRG) built a TBRC with a 100 metric-ton-per-day capacity. This unit was recently installed in a European smelter for processing copper and lead concentrates and lead-zinc flue dust. Processing of battery scrap has also been evaluated with the pilot TBRC (105). In Canada, one copper and one nickel smelter use this technology. Control of SO_2 is accomplished by acid plant or double-alkali scrubbing.

The Outokumpu flash smelting technique, developed in Finland, was recently modified and retested on a pilot scale for direct smelting of lead concentrates. A modification of a copper smelting furnace, the Outokumpu lead smelter is similar to the Kivcet design. As in the other direct smelting methods, thermal efficiency is high and SO_2 concentration is more than adequate for use in an acid plant (greater than 10 percent SO_2). Products include; lead bullion, a slag, dust-laden flue gas and 1.5 to 5 metric tons of dust per hour. These data resulted from pilot tests at the 10,000 to 50,000 metric ton-per-year pilot plants at Pori, Finland, utilizing concentrates containing 40 to 75 percent lead (106, 107). The company stated in 1983 that the process is ready for commercial application.

The Australian ISAMELT process has recently been evaluated for smelting of lead concentrates by Mount Isa Mines, Ltd. (MIM) under a license agreement with the Commonwealth Scientific and Industrial Research Organization (CSIRO) of Sidney Australia. In the ISAMELT process, a submerged combustion lance is used in a simple refractory furnace to directly smelt the sulfide concentrates to bullion with low capital and energy costs (100). MIM plans to utilize the process in the early 1990's if tests continue to be successful. ISAMELT technology has been used for metals recovery from copper and tin slags and could conceivably be applied to lead smelter slags for zinc and lead recovery.

Noranda Mines, Ltd., of Canada has patented a direct smelting furnace for lead concentrates that includes a bullion settling zone and a slag fuming zone in one vessel. The technique, similar to the QSL process, uses a stationary, reverberatory-type furnace. Cominco of Canada patented a direct smelting process incorporating a vertical lance injecting 97-percent-pure oxygen to autogenously smelt lead concentrates charged to the top of a stationary furnace. Additional lead metal is formed by reactions in the molten bath (108, 109).

B. Improvements in Primary Sinter Plant and Blast Furnace Practices

In addition to the recent transition from downdraft to updraft sintering with partial-to-complete sinter offgas recirculation, two other proposed process alterations have potential to improve performance and metal recovery, reduce emissions, and lower costs. The simplest involves constant air volume controls on the blast furnace tuyeres. Sensors are added to each tuyere, sending signals to individual blast air flow controls in response to blast air surges flowing through blow-holes. Sensors and controls compensate for the surges, reduce blow-holes, and control air flows across the furnace. Constant air volume controls were developed at the former Bunker Hill Company's smelter. Controls were applied at a cost of $75,000 per furnace in 1980. The modification increased throughput by 20 percent, availability from 87 to 95 percent over the previous 2 years, and reduced dust emissions associated with blow-hole formation (110).

Another innovation has been demonstrated on a pilot scale at the Hoboken, Belgium, smelter of Metallurgie, Hoboken-Overpelt (97, 111). The Hoboken smelter modifies the sinter feed to limit processing to lead concentrates on the sinter machine. Lead-bearing "secondary" materials are processed in a parallel circuit. The process mixes the secondaries with crushed copper converter slag and the mix is smelted in an electric furnace. Pilot tests indicated a probable energy consumption of about 360 to 410 kilowatt-hours per metric ton of feed to produce lead bullion, speiss (arsenal alloy), copper matte, and metal-rich slag. The slag is mixed with the lead concentrate sinter for charging to the blast furnace. The process reduces the metallurgical complexity and fugitive dust emissions in the sinter plant. Offgases contain about 20 percent SO_2 (97). Other controls applied to existing facilities to reduce fugitive lead-bearing dust emissions include hooding and large increases in the hygiene ventilation volume.

C. Developing Secondary Smelting Technology

In 1983, RSR Corporation announced the development of an electric furnace to recover metal values from reverberatory furnace slag (114). The electric furnace replaced existing blast furnaces. This was the first modern attempt to use an electric furnace in the domestic secondary industry. The process is expected to be less costly and inherently less polluting.

The Bergsoe secondary smelter design has been applied to a new 25,000 ton-per-year smelter at St. Helens, Oregon. The Bergsoe design, an efficient, environmentally clean method for processing lead scrap, is employed throughout Europe and South America. The process uses a large blast furnace to smelt a mixture containing whole batteries, decased battery scrap, and plant waste materials. Fugitive dust emissions are reduced by avoiding the battery breaking process. Fugitive emissions from the furnace charging operation are isolated from the workforce by partitioning the charge area from the furnace area and by using a wheel loader with an isolation cab (115, 116). Another technological development for the control of fugitive emissions is the Bergsoe flash agglomeration furnace. Additional work is required to evaluate the use of this furnace on flue dust in domestic smelters (117, 118).

D. Hydrometallurgical and Electrometallurgical Processes (Primary Lead)

Existing hydrometallurgical processes for treating lead ores have not been applied on a commercial scale, but several have been tested on pilot plant scale, or in extended tests in larger scale laboratory processing units. Electrochemistry is commercially applied in the Betts and the Oroya (Harper-Reinberg) electrolytic refining processes. It is the preferred method for extracting lead as metal in hydrometallurgical processes. Cominco successfully piloted a new bipolar electrorefining process for the Trail, BC smelter (102). Major productivity and occupational hygiene advantages are realized by this new technology. Hydrometallurgy has a number of advantages. Low air pollution is the major inherent benefit. Most hydrometallurgical processes have essentially no lead particulate or sulfur dioxide emissions. Potentially high metal recovery and high metal purity are other benefits of the process Hydrometallurgy processes can be scaled down to a greater extent than current conventional pyrometallurgical smelting, allowing application to small-scale operations. Complex lead-zinc-copper-iron ores difficult to beneficiate can be processed as a bulk concentrate in some hydrometallurgical and electrochemical methods. Such complex, mixed sulfide ores are often avoided for conventional processing in preference to simpler high grade ores. Current flotation methods applied to complex ores to produce individual "smelter-grade" concentrates offer poor resource recovery. Lead hydrometallurgical processes appear to have lower capital costs and are less labor intensive. However, higher energy and reagent costs may make hydrometallurgical operating costs comparable to or higher than pyrometallurgical processing costs.

Before hydrometallurgical processes are applied, environmental hazards and byproduct recovery methods must be investigated. Operation of most hydrometallurgical processes necessitates handling large quantities of corrosive fluids and heating of large volumes of solution.

The U.S. Bureau of Mines developed a hydrometallurgical ore process of ferric chloride leaching of galena concentrate. Followed by reduction by fused-salt electrolysis, lead chloride yielded material which did not require further refining and produced a 99 percent sulfur byproduct with no SO_2 and low lead emissions (fig. 7-1). Computer controls monitored the oxidation/reduction potential of the leaching solution in a bench-scale continuous unit. Results indicated that high lead extraction with low extraction of impurities could be achieved (116). A U.S. Bureau of Mines 500 pound-per-day process demonstration unit completed 18 months of operation in 1981, with very little corrosion of the silica bricks or graphite electrode plates (117, 118). Additional research is required to evaluate the environmental hazards associated with the processing for byproduct recovery and disposal of solid and liquid waste materials from the process (119). Economic evaluation indicated that at the time the process was competitive with conventional pyrometallurgical methods (120). The integrated operation of this leach-electrolysis process (119) indicated that commercial operation is feasible. Identified areas requiring additional research in pilot scale tests include: 1) removal of copper, silver, and, if present, tin 2) removal of sulfates from the concentrate 3) design of pollution control enclosures for leaching and molten metal transfers and 4) alternative cell designs.

In France a similar hydrometallurgical process developed for recovery of lead from galena used a solution of sodium chloride and ferric chloride, but recovered lead powder from the pure lead chloride solution by direct electrolysis (121). Another process using dry chlorination-brine leaching and fused-salt electrolysis was developed on a pilot scale for western lead-silver ores with similar results (122). Overall economics of these processes are uncertain, especially with respect to energy costs.

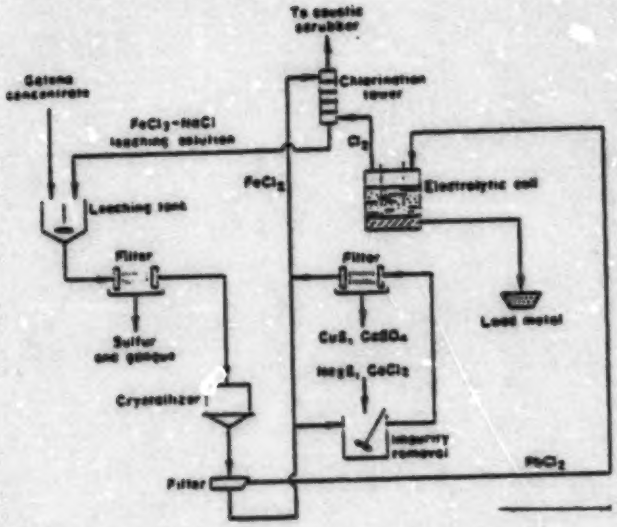
To caustic scrubber
Galena concentrate
Chlorination tower
FeCl3-NaCl leaching solution
Cl2
FeCl2
Electrolytic cell
Leaching tank
Filter
Filter
Sulfur and gangue
CuS, CaSO4
Lead metal
Na2S, CaCl2
Crystallizer
Impurity removal
PbCl2
Filter

FIGURE 7-1.- Bureau of Mines ferric chloride leach- fused salt electrolysis process for primary lead production.

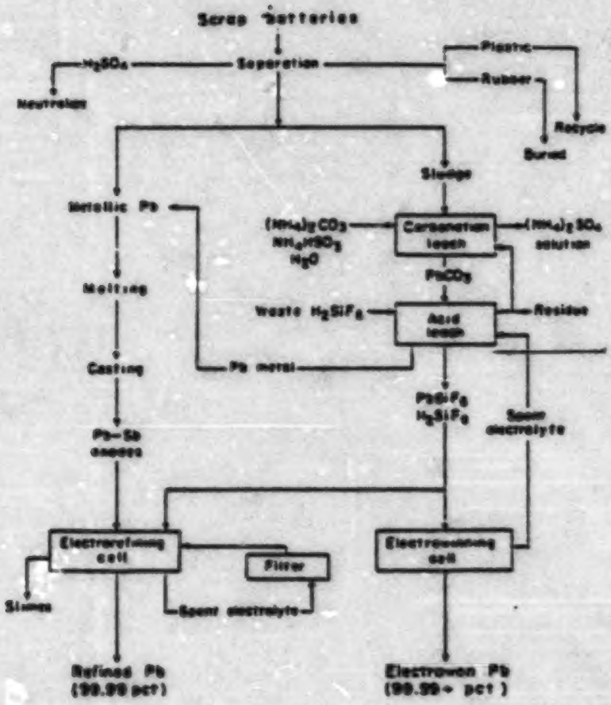
Scrap batteries
Separation
H_2SO_4
Neutralize
Plastic
Rubber
Recycle
Buried
Sludge
Metallic Pb
$(NH_4)_2CO_3$
NH_4HSO_3
H_2O
Carbonation leach
$(NH_4)_2SO_4$ solution
$PbCO_3$
Melting
Waste H_2SiF_6
Acid leach
Residue
Casting
Pb metal
$PbSiF_6$
H_2SiF_6
Spent electrolyte
Pb-Sb anodes
Electrorefining cell
Filter
Electrowinning cell
Slimes
Spent electrolyte
Refined Pb (99.99 pct)
Electrowon Pb (99.99+ pct)

FIGURE 7-2.- Bureau of Mines electrolytic method for lead recovery from battery scrap.

E. Hydrometallurgical and Electrometallurgical Processes (Secondary Lead)

The Bureau of Mines improved an electrochemical method for recycling secondary lead materials that apparently is more energy efficient and creates less pollution than conventional pyrometallurgical smelting. Lead anodes made from scrap battery grid metal were electrorefined to yield cathode deposits of 99.99 percent lead at almost 100 percent current efficiency. Scrap grid metal was cleaned in a ball mill containing ammonium carbonate solution prior to melting to remove the adhering sludge and to eliminate fumes. The resulting material was treated for recovery of lead during the electrowinning phase. A further hydrometallurgical procedure was developed to recover antimony, lead, and other metals from the slimes generated during electrorefining and to recycle the drosses generated from skimming the melt prior to anode casting (123, 124). In tests, hydrometallurgical slimes treatment proved to be inefficient requiring conventional pyrometallurgical techniques. However, tests indicated that some new maintenance-free batteries produce very little slime that would hinder operations and require treatment (E. Cole, BOM, Oral Communication, 1983). Based on bench scale tests, the Bureau developed a proposed plant design for the processing of 10,000 batteries per day or about 100 tons/day (fig. 7-2). Preliminary cost estimates indicate a capital cost of the design of about $21 million with operating costs about 35 cents/kg (16 cents/lb). This excluded the cost of scrap purchases (4 to 6 cents/lb) and complete solid waste disposal or treatment costs, which could be offset by byproduct sales (125).

RSR Corporation announced receipt of three patents during 1981 on its hydrometallurgical process for recycling battery sludge (126). This process is similar in some aspects to the Bureau of Mines process.

In 1981, an Italian engineering firm announced that it would license its electrochemical technique for reclaiming battery lead. The Ginatta process, as it is known, involves shearing the bottoms from spent batteries and direct immersion in an electrolyte prior to metal recovery, using a combination of electrowinning and electrorefining (126).

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